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PATHWAYS IN SCIENCE

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S I METRIC EDITION

JOSEPH M. OXENHORN

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oceans of air and water

PATHWAYS IN SCIENCE

BIOLOGY 1—The Materials of Life
BIOLOGY 2—Built for Living
BIOLOGY 3—The Next Generation

EARTH SCIENCE 1—The Earth We Live On
EARTH SCIENCE 2—Oceans of Air and Water
EARTH SCIENCE 3—Man and Energy in Space

CHEMISTRY 1—The Materials of Nature
CHEMISTRY 2—Chemistry of Mixtures
CHEMISTRY 3—Chemistry of Metals

PHYSICS 1—The Forces of Nature
PHYSICS 2—Matter and Energy
PHYSICS 3—Sound and Light

GLOBE BOOK COMPANY

earth science

2

oceans of air and water

S I METRIC EDITION

JOSEPH M. OXENHORN

Edited by
PETER GREENLEAF

Globe/Modern Curriculum Press

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Introduction to the Students

Welcome to your new science book, *Pathways in Science!*

A pathway is a road, a street or an avenue which leads you somewhere. *Pathways in Science* is a book that will lead you to a greater understanding of science.

This section of *Pathways* is called *Oceans of Air and Water*. In this section, you will be studying a branch of science called "earth science." Earth science is the study of the earth: what it looks like, what it is made of and how it came to be. It is an exciting science and will answer many questions for you.

Pathways is a tool to help you learn. A good mechanic knows his tools. A good student knows how to use his book.

Let us study the organization of the book and see how to use it.

ARRANGEMENT

At the front of the book is a *Table of Contents*. This table or list tells you what you can find in the book. It tells you on what page each part of the book can be found.

The book can be divided into four parts called *Units*.

Unit I	Review and Preview	page 1
Unit II	Our Ocean of Air	page 19
Unit III	Predicting the Coming Weather	page 79
Unit IV	The Waters of the Ocean	page 123

Each Unit is divided into *Chapters*. Each chapter begins with a *Target Question* which is answered by material in that chapter. For example, on page 3, you will find Chapter 1. The Target Question is "What do I remember about the earth?"

Each chapter is divided into *Paragraphs* which have a number. Turn to page 3. There you will find paragraph 1, *What's Ahead?* Paragraph 2 on the same page is titled *The Earth in Space.*

Every few paragraphs, you will find a section called *You Now Know.* Turn to page 5 for an example. This is a kind of summary of what you have just read. It helps you review. It helps you remember.

At the end of each chapter, you will find questions which help you find out how much you have learned. Turn to page 8. There you will find the section called *Understanding What You Have Read.* In addition to the questions, you will also find suggestions for exciting things you can do at home. Look at page 34 in Chapter 4. Question VII is *For the Home Scientist.*

NEW SCIENCE WORDS

Science has its own language. It has new words which have a special meaning. Some of these new words are unfamiliar. The book tells you how to pronounce these words. Turn to page 3. In paragraph 2, we use the word CONTINENTS. Notice how it is pronounced: (KON-ti-nents).

At the end of each Unit, there is a *Glossary.* Turn to page 16. Notice that the words are arranged in alphabetical order. In Column 2, the words are pronounced. In Column 3, there are simple definitions.

PICTURES AND DIAGRAMS

The book has many pictures and diagrams, called figures, to help you "see" science ideas. All pictures and diagrams are numbered in such a way that you can find them quickly. For example, Fig. 4-1 means the first picture on page 4. Fig. 4-2 means the second picture on page 4.

INVESTIGATIONS

Pathways has many *investigations.* Some of them you will see your teacher do in class. Some you will do in class by yourself or with a partner. Some you can do at home. Experiments are jobs that give a scientist answers. They are great fun and a good way to learn. A list of the investigations can be found on page ix.

SOME HINTS FOR A GOOD STUDENT

1. Listen carefully to your teacher.
2. Watch the experiments.
3. Get a good notebook. Keep it clean and neat.
4. Do your homework every day.
5. Read the book carefully. If you don't understand something the first time, read it again.
6. If you need more help, ask your teacher.
7. Don't mark up your book. Keep it clean.

AND REMEMBER . . .

School can be fun. School means learning. If you study today, you will succeed tomorrow. Good luck!

THE AUTHOR

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UNIT I

The earth may have been formed at the same time as the sun. When the young earth finally cooled, life formed. The first bird and several prehistoric animals are shown. Many early human-types appeared on the earth thousands of years ago.

REVIEW AND PREVIEW

UNIT I

Review and Preview

CHAPTER 1. THE EARTH AND ITS SURFACE

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TARGET
What do I remember about the earth?

The Earth and Its Surface

Fig. 3–1

Man is now exploring the atmosphere first-hand.

1. WHAT'S AHEAD?

In this book we shall study *earth science*. First, we shall "zero in" on the ocean of air, the atmosphere. We shall learn about the wonders of air pressure and the work of the weathermen. Then we shall "zero in" on the oceans. In that study, we shall find out that scuba divers, biologists, frogmen and geologists have made a new team. We shall share with them the secrets of the deep Pacific Ocean, the blue Caribbean Sea and the wild Atlantic Ocean. First, however, we shall refresh our memories of what we have already learned. Off we go!

2. THE EARTH IN SPACE

If you were a spaceman circling the earth in your spaceship, you could look down upon the earth. What would you see? You would see a huge ball (a sphere) which spins in space like a top. You would see that about one-quarter of the surface of the earth is land. These masses of land form CONTINENTS (KON-ti-nents). Three-quarters of the surface of the earth is covered by water—bays, seas and oceans. The solid part of the earth's

Fig. 4–1

This picture was taken by astronauts as their spaceship circled the moon. The earth (in the distance) is spinning in space.

surface is called the LITHOSPHERE (LITH-o-sfeer). All the water on the surface is called the HYDROSPHERE (HY-dro-sfeer). Surrounding all the earth's land and water is a blanket of air called the ATMOSPHERE (AT-mo-sfeer).

3. HOW WAS IT FORMED?

How was the earth formed? How did it get to look the way it does?

The chart below Fig. 4-2 is called a "time line." It shows you how old our earth is.

Some scientists believe that a large mass of gas and dust formed our *sun* and nine smaller bodies, the *planets*. As these planets cooled, they contracted (grew smaller) and heated energy was given off. This was about six billion years ago.

One of these planets is our earth. Like our earth, the other eight planets spin like tops (rotate) on their axes.

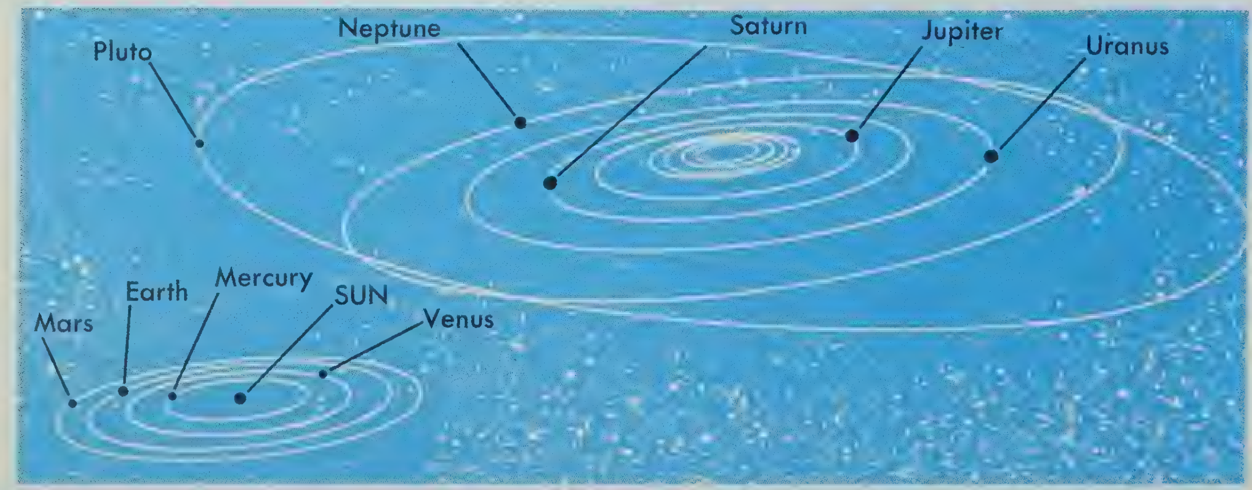


Fig. 4–2

Our solar system has the *sun* at its center. All nine planets revolve around the sun in paths called ORBITS (ORE-bits).

Time before any life: About 5 billion years	Before written history: 1 million years	Ancient people: 6000 years	Modern people: 2000 years

4. THE EARTH COOLED AND SHRANK

Have you ever held a hot baked potato? The outside cools first. The middle of the potato cools last. So it was with the earth. How does this explain why the inside of the earth is still hot?

As the earth's surface cooled, it shrank and became wrinkled. High spots formed hills and mountains. Some of the gases condensed into water. The water flowed into the lower spots to form rivers, bays and oceans. Other gases stayed above the surface of the earth to form the layer of gas called the atmosphere.

5. HOW OLD IS THE EARTH?

We cannot answer this exactly. But chemists and geologists give us three ideas which we can use to estimate the age of the earth by scientific methods. First, we can use the idea that uranium in rocks changes to lead at a *steady* rate of radioactive change. Second, we learned that the amount of salt in the seas increases at a *steady* rate. And third, we learned that the sediment in the sea is laid down at a *steady* rate. All these changes can be measured to give us the age of the earth. The chart below tells the story.

YOU NOW KNOW

- The earth is a huge ball of solid land (lithosphere) covered by water (hydrosphere).
- The earth is surrounded by a layer of gases called the atmosphere.
- The earth is about 6 billion years old.

6. WHAT COVERS THE EARTH?

The earth is covered with soil, sand, rocks and minerals. As we know, this solid part of the earth is called the *lithosphere*. Rocks were formed by heat, water and pressure. The molten (melted) rock called MAGMA (MAG-ma) cooled and shrank to form IGNEOUS (IG-nee-us) rocks. Broken-down rocks form sediment underwater. They are later cemented together to become SEDIMENTARY (sed-i-MEN-tuh-ree) rocks. Both igneous and sedimentary rocks are acted upon by heat, pressure and chemicals. When this happens, they become METAMORPHIC (MET-a-MOR-fik) rocks. Rocks contain minerals of many kinds. Sand and soil are formed from the rocks and minerals.

THREE GROUPS OF ROCKS

Igneous Sedimentary
Metamorphic

FINDING OUT THE AGE OF THE EARTH

1. Radioactive Minerals
2. Salt in the Sea
3. Thickness of Sediment in the Sea

4 to 6 Billion Years

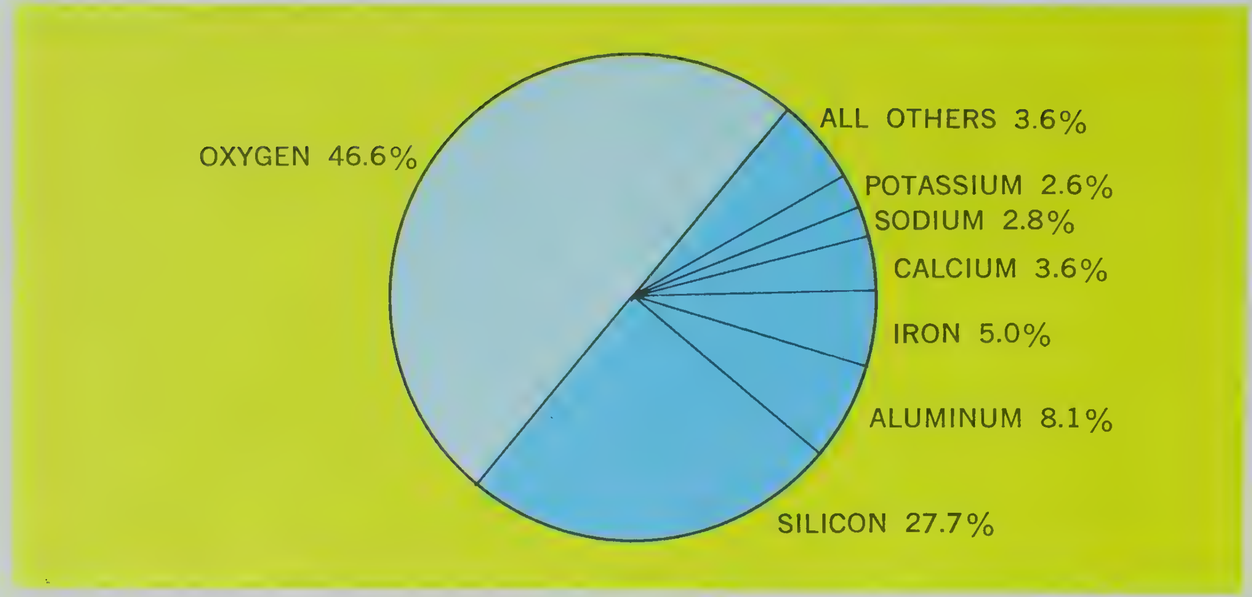


Fig. 6–1

Seven elements make up over 96% of the earth.

7. THE EARTH'S SURFACE CHANGES

The earth's surface has changed very much since it was formed. It is still changing. It is changed by the forces of WEATHERING (WETH-er-ing) and EROSION (ee-ROE-zhun). Wind, water and ice erode the earth's crust. They wear away and move rocks, minerals and soil. They erode our ocean beaches and cut rivers. The soil is carried to the river's mouth where it forms a delta.

8. THE WATERS OF THE EARTH

About three-quarters of the earth's surface is covered by water. Oceans, seas and bays are large bodies of water that sometimes separate continents. On the continents there are rivers, streams, lakes and solid GLACIERS (GLAY-shurs). Our envelope of air,

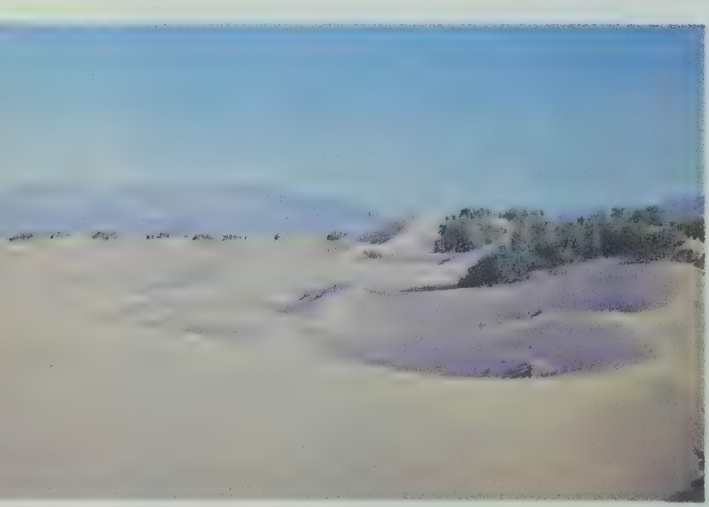


Fig. 6–2

Sand dunes form hills and are rippled by the wind. What is the force at work?

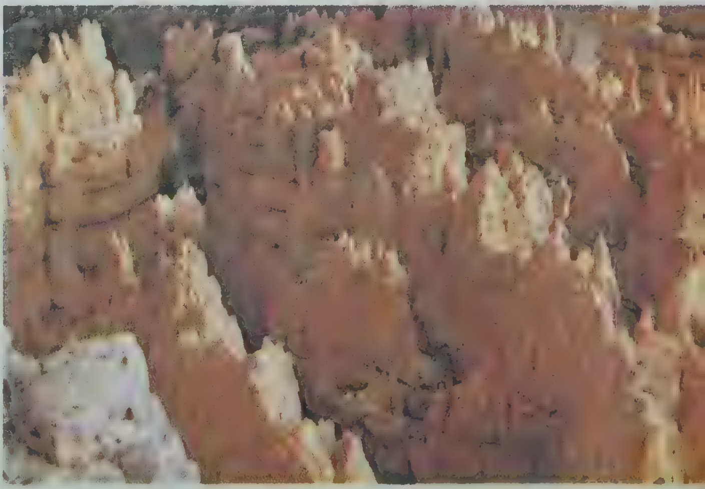


Fig. 6–3

Thousands of years of erosion shaped this strange rock.

the atmosphere, contains large amounts of water in the form of vapor.

SALT WATER	Oceans Seas Bays
"FRESH" WATER	Rivers Lakes Streams Snow

YOU NOW KNOW

- The lithosphere is made up of rocks, minerals, soil and sand.
- Rocks are igneous, sedimentary or metamorphic, depending on how they were formed.
- The earth's surface has changed and keeps changing because of the forces of weathering and erosion.

9. AIR, WATER AND HUMAN WELFARE

We live in the atmosphere and depend on it for many of our activities. We breathe the air. We eat the plants which grow in the air by capturing the sun's energy. Our seasons, our climate and our daily weather are controlled by the air.

The waters of the earth support living things and thus control the balance of nature. Our waters support ocean life which provides much of our food. Our oceans, as you will see, are sources of many useful products.

Fig. 7–1

How are our seasons, climate and daily weather controlled by the air?

Our transportation systems, from place to place, use the atmosphere and the hydrosphere. Sailing and rafting have been known from ancient times. Later, sailboats, schooners and modern ocean liners were built "to ride" the currents and waves. The development of airplanes gave us "the wings of man" and the world has grown "smaller." Today, radio communication keeps the whole world informed by sending knowledge through the air.

No wonder the sciences dealing with atmosphere and hydrosphere have grown so fast! No wonder so many people find their careers in these fields! No wonder that federal governments have developed special agencies to study these fields. If you would like to know more about this work, write to the above agencies. Ask for information. It is free. Also, your own state, province, county or city may have similar agencies.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 1?

1. Continents are land masses.
2. The earth is one planet in our solar system.
3. The earth consists of the lithosphere and the hydrosphere.
4. The earth's surface is ever changing.

II. In which paragraph do you find the answer?

1. How much of the earth's surface is land?
2. How were rocks formed on the earth?
3. What does erosion do to our earth?
4. What is a time line?

III. Knowing What and Why

1. The age of the earth is estimated to be
   - a. between one and two billion years.
   - b. over twenty billion years.
   - c. between four and six billion years.
   - d. very old, but an estimate is impossible.
2. Molten rock is also called
   - a. magma.
   - b. igneous.
   - c. sedimentary.
   - d. metamorphic.
3. Ninety percent (90%) of the earth is made up of
   - a. 92 elements.
   - b. about 50 elements.
   - c. 6 elements.
   - d. 102 elements.
4. The smallest concentration of salt is usually found in
   - a. seas.
   - b. streams.
   - c. bays.
   - d. oceans.

IV. Select the word in parentheses that best matches the underlined word.

1. weathering (erosion, cooling)
2. hydrosphere (river, valley)
3. uranium (lead, magma)
4. rotation (oxidation, spin)
5. water (sedimentary rock, igneous rock)
6. three-quarters of the earth (water, air)

V. True or false? Why?

1. Water is found only in the hydrosphere, never in the atmosphere.
2. Parts of the earth are still very hot.
3. Igneous rocks are most like magma.
4. Erosion can also be useful.

VI. Understanding the Diagrams and Photos

Explain your answers.

1. In Fig. 4–2, which planet is closest to the sun?
2. In Fig. 6–1, which element forms the largest amount of the earth? Which element forms the least?
3. In the photograph in Fig. 6–3, what kind of rock might this be?

2

TARGET
What is known about the atmosphere?

The Atmosphere Is an Ocean of Air

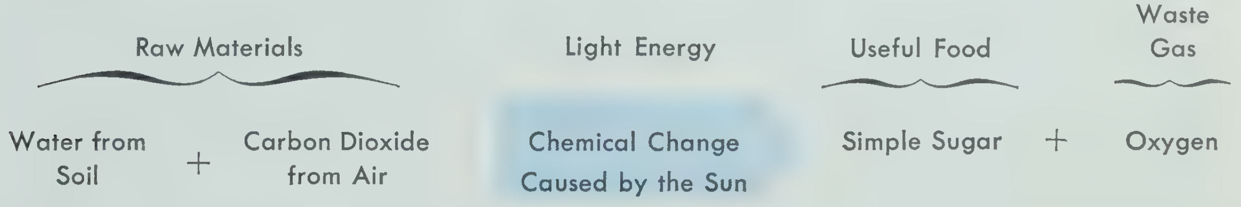
1. ATMOSPHERE AND LIFE

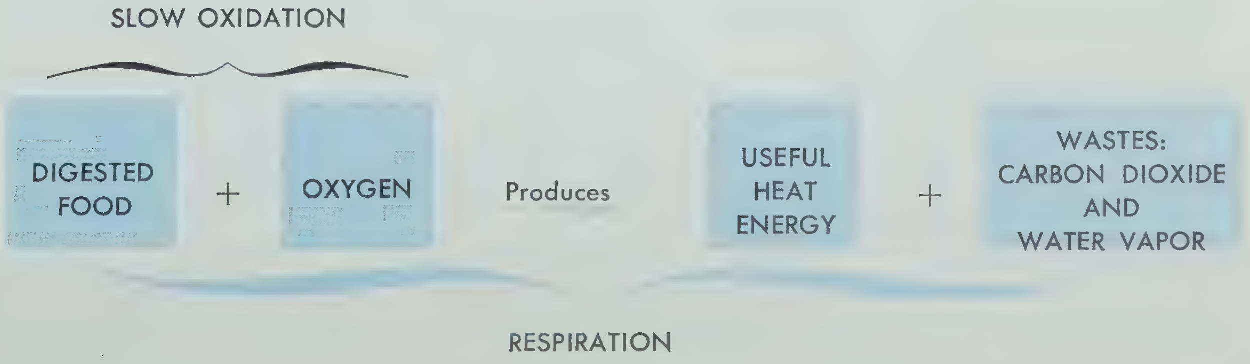
Without atmosphere life would be impossible. The atmosphere contains gases needed for life. Most of the animals we know breathe in air to oxidize food for heat and energy. Green plants need the CO_2 of the atmosphere in order to make their own food. They also need oxygen for energy.

The oxygen in the atmosphere helps us burn fuel to get heat energy. Most of our energy for transportation and industry comes from such heat energy. Later, we shall see how air pressure works for us.

2. AIR IS MATTER

Empty glasses are not really empty.





$$\overbrace{\text{FUEL} + \text{OXYGEN}}^{\text{OXIDATION}} \longrightarrow \text{HEAT ENERGY} + \text{NEW COMPOUNDS}$$

Produces

$$\underbrace{\text{CARBON} + \text{OXYGEN}}_{\text{OXIDATION}} \longrightarrow \text{HEAT ENERGY} + \text{CARBON DIOXIDE}$$

They are filled with air. Our rooms are filled with air. Our earth is surrounded by air. Air is really matter but it's in the gaseous phase. When you buy a tube for your bicycle tire, it is packed in a small box. After you fill it with air, it cannot be put back into the box. The air in the tube takes up space. A toy balloon can fit into your pocket when it is empty. When

Fig. 10–1

Modern planes, speeding through the atmosphere, have made our world a smaller and friendlier place.

it is blown up, it can no longer fit into your pocket. Examine the demonstration in Fig. 11-1.

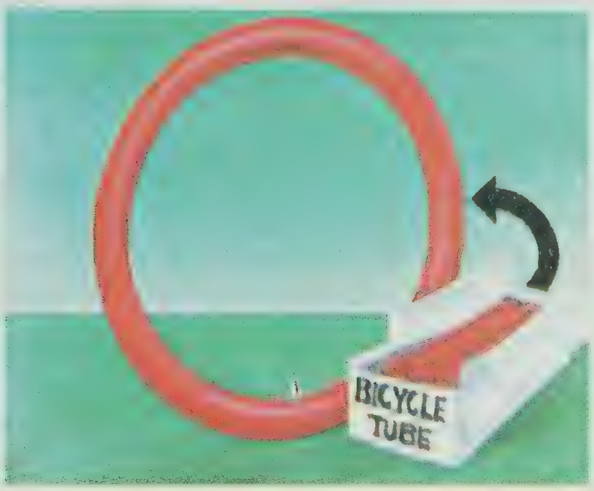


Fig. 11–1

Is the tube in the box empty? Why does the air in the tube at the left not escape?

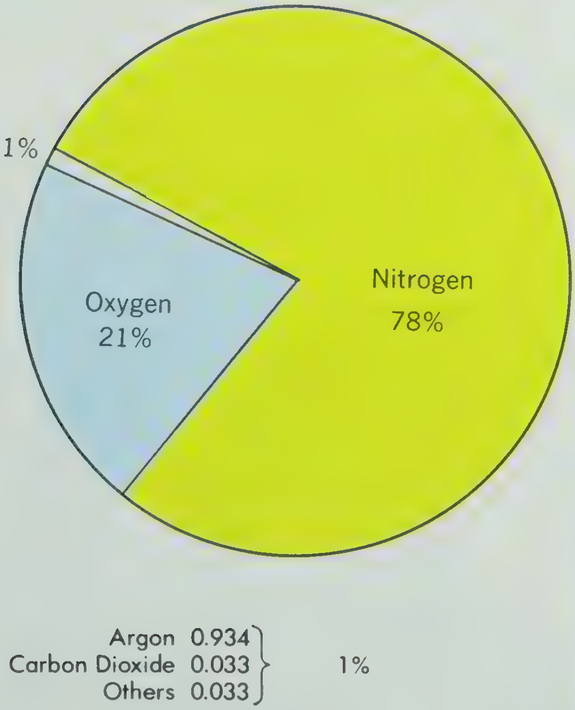


Fig. 11–2

This chart shows the composition of air. Which are the elements? Which are the compounds?

3. AIR IS A MIXTURE

The air is a mixture of gases. Some are elements; some are compounds. Mixed in with these gases are particles of dust, smoke and water. The chart below reviews the approximate composition of air. It is approximate because all mixtures have a changing composition. You will see why later.

DO AND DISCOVER

Investigation 1: Is air matter?

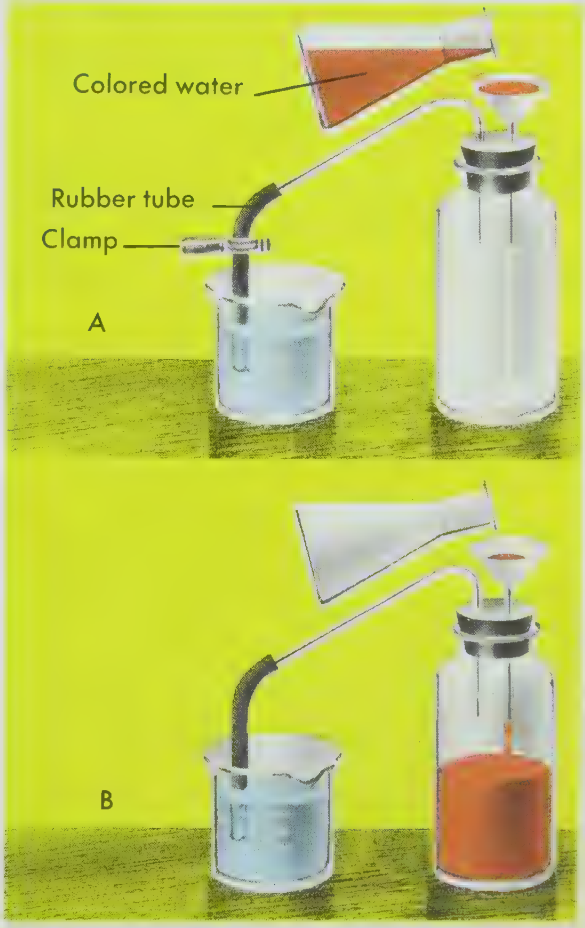


Fig. 11–3

Why can't all the water in Diagram A flow down into the bottle from the funnel? Why does the water flow down in Diagram B? What are the bubbles in the beaker in Diagram B?

4. AIR EXERTS BUOYANCY

The atmosphere is a fluid, like the ocean. Therefore, *Archimedes' Laws of Floating* act in the air exactly as they do in the ocean. Balloons filled with gases lighter than air, such as helium, displace as much air as the volume of the balloon. The force of the air pushes upward on the balloon. It moves upward until it reaches a level where it displaces a mass of air equal to its own mass and floats! When the balloon floats, we say it is BUOYANT (BOY-ant).

5. WHAT FORCES WORK IN THE ATMOSPHERE?

Light energy from the sun and other stars passes through the atmosphere to the earth. We all know that the pull of gravity goes right through the air. Magnets can attract metals through the air. The atmosphere controls the passage of other energy waves: ultraviolet rays, X rays, cosmic rays and radio waves.

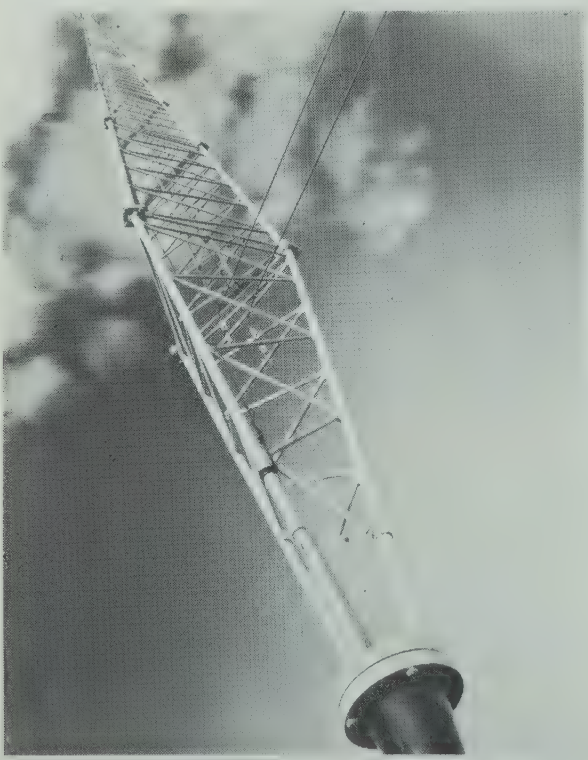


Fig. 12–1

Waves are sent out of this antenna. They move through the air to our radio and TV receivers.

6. HOW DO SCIENTISTS STUDY THE ATMOSPHERE?

Your first answer might be, "Go up into the atmosphere." Of course, you are right. It has been done. Mountain climbers, pilots and astronauts have been high up and have collected information about the atmosphere. Sometimes, they have used unmanned balloons to take instruments aloft. When the instruments return, the scientists read the results.

There is a second way, a "stay-at-home" way. In 1868, a new gas was observed in the light of the sun with an instrument called a SPECTROSCOPE (SPEK-tro-skope). This gas had never been seen on earth. But 27 years later, in 1895, the gas, now called *helium*, was discovered in wells in the oil fields of Texas!

The scientists who study the atmosphere belong to many fields. There are biologists who study the effects of atmosphere on life. Chemists study its composition. There are weather and radio experts and space scientists. These are only a few examples.

7. LAYER UPON LAYER

Scientists have found that the atmosphere is not just one layer of air. Actually, we can draw a map of the atmosphere. Study Fig. 13-2. It shows that our atmosphere consists of four layers. Of course, there is no sharp line between the layers. These divisions are only imaginary.

The bottom layer is one that is closest to our earth. This layer is called the TROPOSPHERE (TRO-po-sfeer), the zone of active air currents. This is where our weather is born. It reaches up to 12 km above the surface of the earth. The next layer is the STRATOSPHERE (STRAT-o-sfeer). It reaches up to 32 km above the earth. Here we find air currents moving from side to side. This is the zone in which we fly jet planes and manned balloons. Above this layer is the IONOSPHERE (eye-ON-o-sfeer), the zone of charged particles, which reaches up about 425 km. The last zone shown on our map is the outer zone, the EXOSPHERE (EX-o-sfeer). It extends to about 950 km above the earth. After 950 km above the earth, we are in outer space. Later, we shall study temperature changes in the various layers.

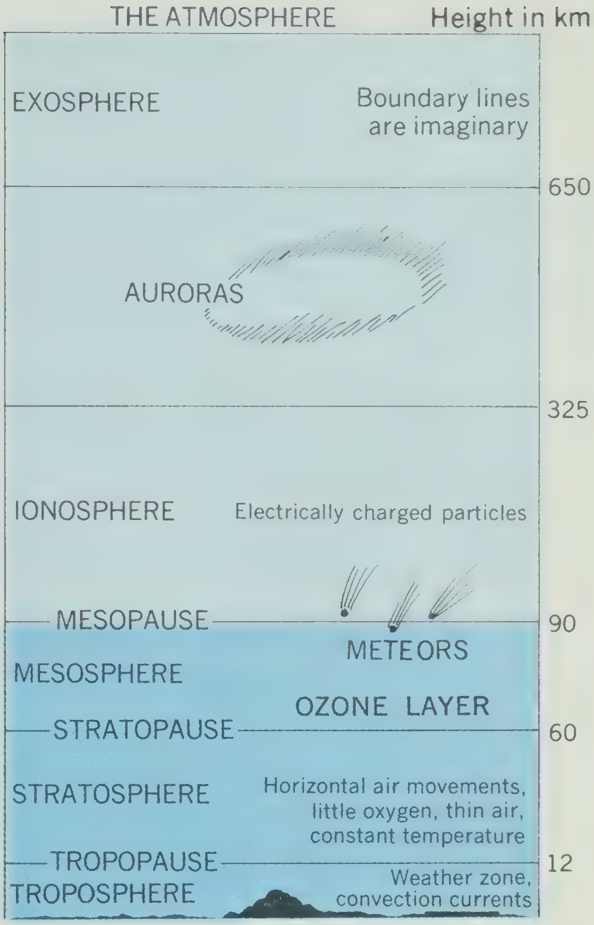

THE ATMOSPHERE
Height in km
EXOSPHERE
Boundary lines are imaginary
650
AURORAS
325
IONOSPHERE
Electrically charged particles
MESOPAUSE
90
METEORS
MESOSPHERE
OZONE LAYER
STRATOPAUSE
60
STRATOSPHERE
Horizontal air movements, little oxygen, thin air, constant temperature
TROPOPAUSE
12
TROPOSPHERE
Weather zone, convection currents

Fig. 13–2

This chart shows the layers of our atmosphere.

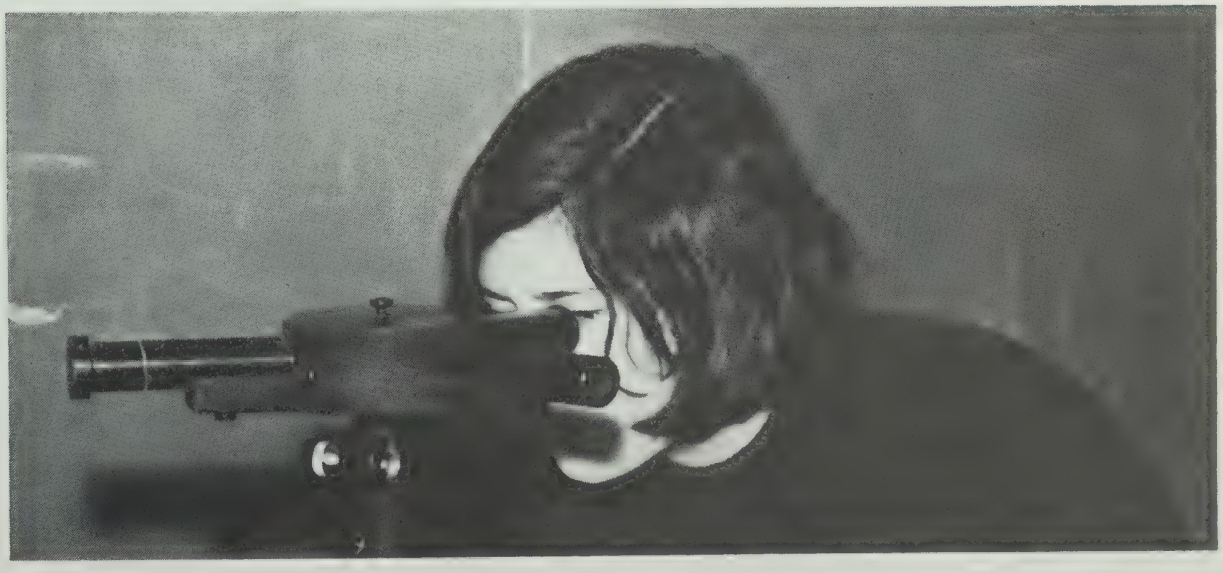


Fig. 13–1

The spectroscope is used to study light in a laboratory. Other instruments are used to study the behavior of sound waves, radio waves and light waves.

PROFILE OF A GREAT SCIENTIST

Archimedes 287 B.C.-212 B.C.

Archimedes was born in Greece. He was the greatest scientist of ancient times. In addition, he was a colorful man about whom many interesting stories were told.

As you read before, he developed the laws which explained why objects float in air, or in water. According to the legend, King Hieron asked Archimedes to find out whether the king's new crown was all gold, or a fake, with some silver in it. Archimedes could not test the crown by scratching it, or chipping away pieces.

One day, Archimedes stepped into his bath and noticed that the water level rose higher. Of course! His body had a certain volume. Now, thought Archimedes, could pure gold make the water rise a different amount than a gold-silver mixture?

Archimedes became excited, dashed out of the tub and ran straight to the palace—naked! As he ran, he shouted, "Eureka! Eureka!" (I have found it!)

The legend further tells that the experiment was done with the crown; it was found to be not pure. The goldsmith was put to death!

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 2?

1. The atmosphere is a mixture of gases.
2. The atmosphere supports photosynthesis.
3. The atmosphere is made of different layers.
4. Gravitational pull surrounds the earth.

II. Explanation, please . . . answer in one or two sentences.

1. Do Archimedes' Laws of floating bodies apply to the atmosphere?
2. Can X rays pass through the atmosphere?
3. Does air take up space?
4. What is the stratosphere?

III. Knowing What and Why

1. A spectroscope is used to study the composition of the sun by
   a. analyzing the ionosphere.
   b. going up in a space capsule.
   c. going up in a balloon.
   d. examining light.
2. Atmosphere is a real form of matter because it
   a. has mass and can support photosynthesis.
   b. has mass and takes up room.
   c. extends above the earth.
   d. is a mixture.
3. The atmosphere supports life through
   a. photosynthesis and pressure.
   b. oxidation and food-making.
   c. food-making and weather.
   d. oxidation and respiration.
4. Jet planes fly in the
   a. troposphere and stratosphere.
   b. troposphere and ionosphere.
   c. ionosphere and stratosphere.
   d. atmosphere and outer space.

IV. Understanding the Diagrams

1. In Fig. 11—1, if the artist did not want to use a bicycle tire, what else could he have shown?
2. In Fig. 11—2, if you wanted to show this idea on a bar graph 100 cm long, how many centimetres would you use for oxygen?
3. In Fig. 11—2, what do the numbers stand for?
4. In Fig. 11—3, why do we use colored water? Why do we make sure the stopper is very tight in the neck of the bottle? Could you do this experiment without a funnel? How?

V. Finish the story by choosing the correct words from the list that follows.

Our earth is surrounded by the (1) which is a (2) of (3). The atmosphere is made of many (4), one on top of the other. The closest layer to our earth is the (5). Combustion and respiration depend on the (6) in the air, while photosynthesis depends on the (7). Air takes up (8) and has (9). The ionosphere is dangerous to life because it contains (10).

mixture
layers
oxygen
nitrogen
atmosphere
space
charged particles
CO_2
troposphere
gases
helium
mass

VI. Explanation, Please

1. When you blow up a toy balloon and let it fly high in the sky, it might burst.
2. Why do you punch *two* holes in a can of juice?
3. What are the advantages of using unmanned balloons to go aloft? What are the disadvantages?

Glossary: What Does It Mean?

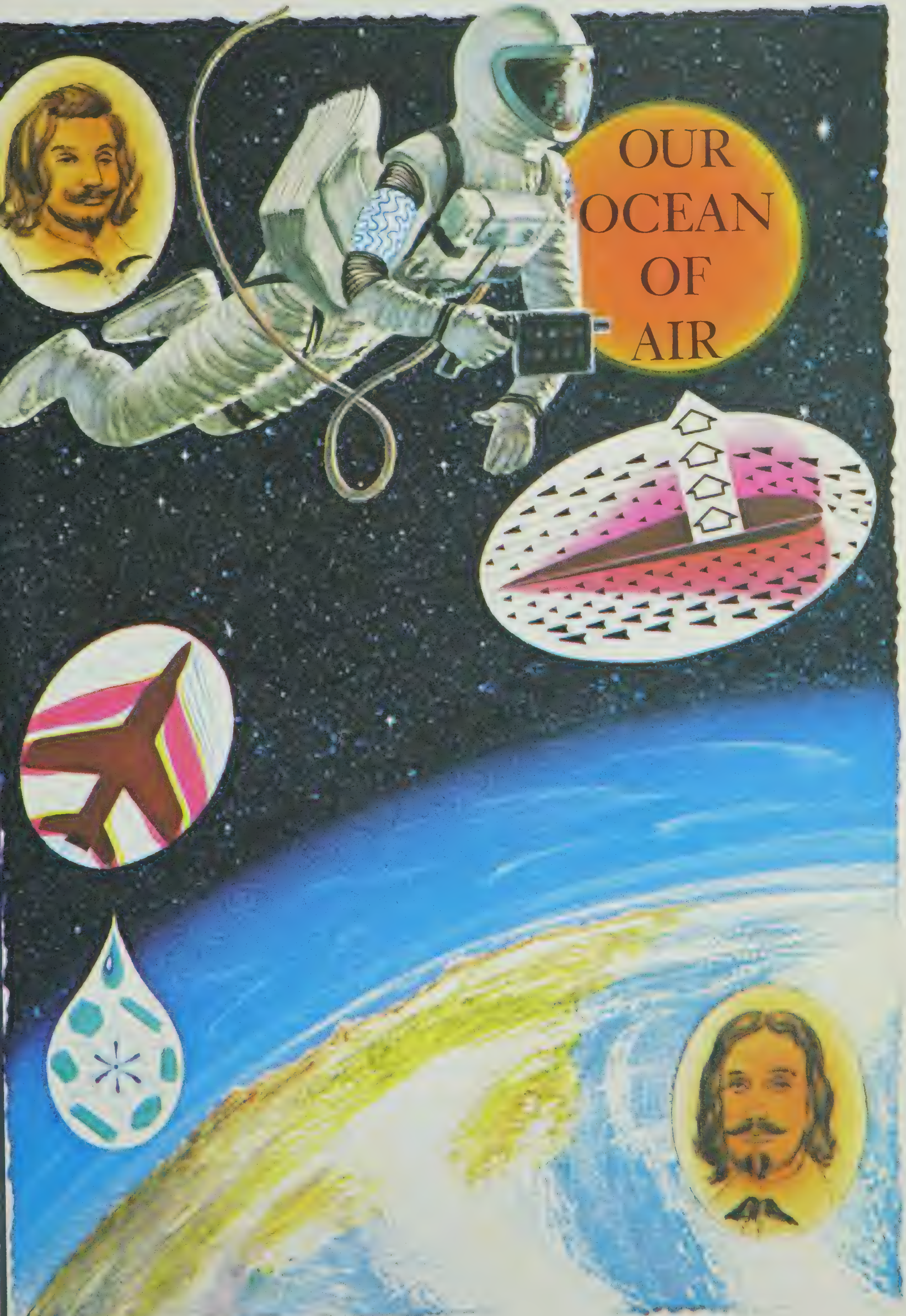
Archimedes	ar-kuh-MEE-deez	The Greek scientist who discovered the Laws of Floating.
atmosphere	AT-mus-feer	The mass of air surrounding the earth.
buoyant	BOY-ant	The ability to float or rise in a fluid.
continents	KON-ti-nents	The six large land masses on the earth.
erosion	ee-ROW-shun	The wearing away of the earth's surface by natural forces such as wind or water.
exosphere	EX-o-sfeer	The outermost layer of the earth's atmosphere.
fluid	FLOO-id	Another name for the liquid and gas phases of matter.
glacier	GLAY-shur	A large mass of moving ice on land.
helium		A gas which is lighter than air and does not burn.
hydrosphere	HY-dro-sfeer	The water which covers the earth's surface.
igneous	IG-nee-us	A type of rock formed by the cooling of magma.
ionosphere	eye-ON-o-sfeer	The layer of the atmosphere above the stratosphere; contains charged particles.
lithosphere	LITH-o-sfeer	The solid rock that covers the earth's surface.

magma	MAG-ma	Molten rock below the earth's surface.
metamorphic	MET-a-MOR-fik	A type of rock that has been changed from its original form by heat and/or pressure.
minerals		Chemical elements or compounds that are found in or on the earth.
mixture		A combination of elements or compounds in no fixed amounts.
orbit	ORE-bit	The path in which a planet or object revolves around another object. An example is the earth revolving around the sun.
phase	FAYZ	Any one of the forms in which matter may exist.
planet		Any of the nine heavenly bodies that revolve around the sun.
sedimentary	sed-i-MEN-tuh-ree	A type of rock formed in layers from materials deposited in water.
spectroscope	SPEK-tro-skope	An instrument used to study light waves from various objects.
stratosphere	STRAT-o-sfeer	The layer of air above the troposphere, 10 to 32 km above the earth.
troposphere	TRO-po-sfeer	The layer of air next to the earth's surface. It is here that our weather is formed.
weathering	WETH-er-ing	The breaking down of rocks and minerals by temperature changes, oxidation and so forth.

UNIT II

The man in the top left is Evangelista Torricelli, the inventor of the mercury barometer. The astronaut wears a spacesuit of several layers of material to protect him from the temperature and vacuum of space. In the middle right is a side view of an airplane wing. It shows how the air passes over the wing creating a lower pressure on the top of the wing than on the bottom. To the left is an airplane flying at speed faster than sound and the air waves it creates. The blue band around the earth represents the earth's atmosphere. The drop to the left represents the water in the atmosphere. At the bottom right is the Mayor of Magdeburg. He studied the effects of air pressure.

OUR OCEAN OF AIR



UNIT II

Our Ocean of Air

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3

TARGET
How can we explain the pressure of our atmosphere?

The Air Exerts Pressure

1. A STRANGE MAYOR

Otto von Guericke (GER-i-kee) was the mayor of a German town called Magdeburg about 1650. In addition to being mayor, his hobby was science. In one of his experiments he made a pair of steel HEMISPHERES (HEM-i-sfeers) or half-spheres. He fastened them together and then took most of the air out of the inside of the huge ball. Sixteen horses were unable to pull the half-spheres apart. Then with a flip of his hand, he opened a valve to let air in again. The two sections fell apart at once. Would you like to know his secret?

2. AIR HAS MASS

Since air is matter, it has mass and takes up space.

The mass of air has been checked very carefully. A litre of air has a mass of 1.29 g. *Reminder:* a litre is a volume of space 10 cm long ×10 cm wide × 10 cm high.

AIR IS MATTER

IT HAS MASS

IT TAKES UP SPACE

3. A LESSON FROM A CRUSHED CAN

It is easy to get a can like the one shown in Fig. 24-1. This can is not empty; it contains air. Now let us fit the opening with a one-hole rubber stopper and a glass nozzle. We attach a pump that pulls the air out. You can see the results for yourself! What caused this to happen? Normally, the air pressure inside the can balances the pressure outside. But then we removed the air from inside. The giant pressure of the atmosphere pushed against the sides of the can. Since there was almost no air inside, there was less air pressure inside to push against the outside pressure. The can was crushed out of shape.

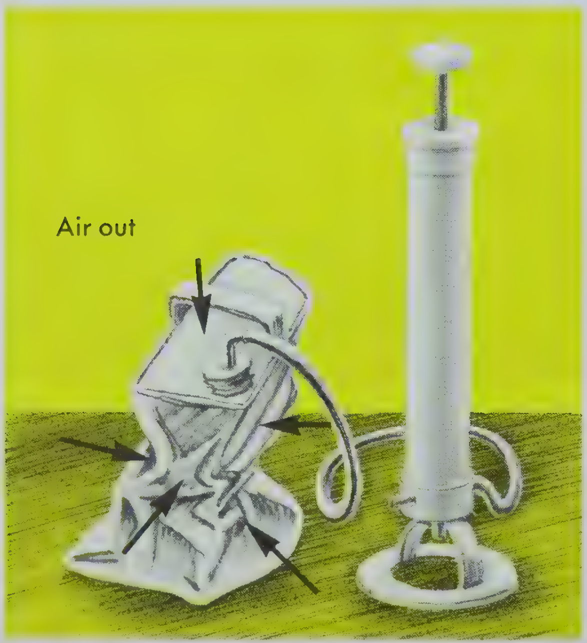


Fig. 24–1

Can the shape of the can be brought back to normal? Explain.

DO AND DISCOVER

Investigation 2: Does a balloon filled with air weigh more than an empty balloon?

You can easily find out if gas has mass. Fill up a toy balloon by blowing air into it. When it is fully blown up tie the open end shut. Put the balloon on one side of a platform balance. Put a dish of sand on the other side of the balance so that it is balanced. Both sides will weigh the same. Now open the balloon and let the air out. As the air escapes from the balloon, that side of the balance will rise slowly. Why?

4. WHICH WAY DOES THE PRESSURE PUSH?

Look carefully at the can in Fig. 24-1. You can easily see that the can is crushed on all sides. This can mean only one thing; air pressure acts in all directions. Let us show this in another way. Examine Fig. 25-2. Notice that in each case, we exhaust the air from inside the funnel.

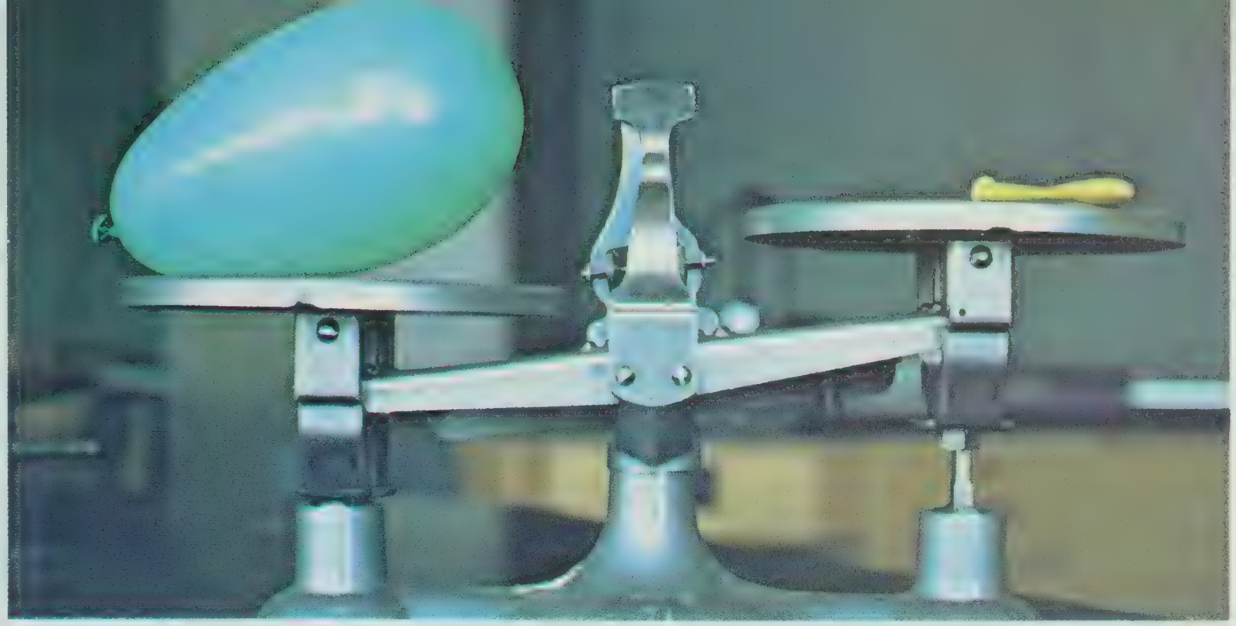


Fig. 25–1

A balloon filled with air is heavier than an empty balloon.

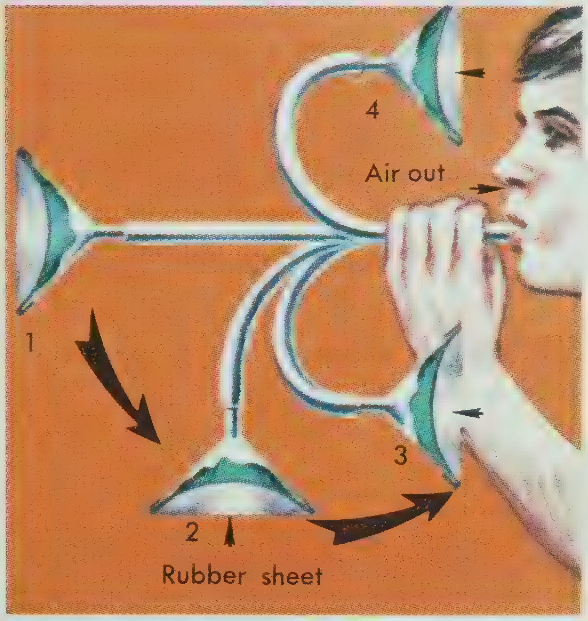


Fig. 25–2

As you remove air from the funnel, the atmosphere pushes the rubber membrane inward. It makes no difference in which direction you hold the funnel at any given height.

YOU NOW KNOW

- Air exerts pressure.
- Air pressure pushes equally in all directions at a given height.

5. MORE WAYS TO SHOW AIR PRESSURE

DO AND DISCOVER

Investigation 3: How can we show air exerts pressure?

There are other simple ways to show that air exerts pressure. In Fig. 25–3 A, we fill a glass with water up to the very top. Cover the glass with a piece of cardboard. Slowly turn the glass over, holding it over the sink. Why does the cardboard stay in place? Why does the water not run out?

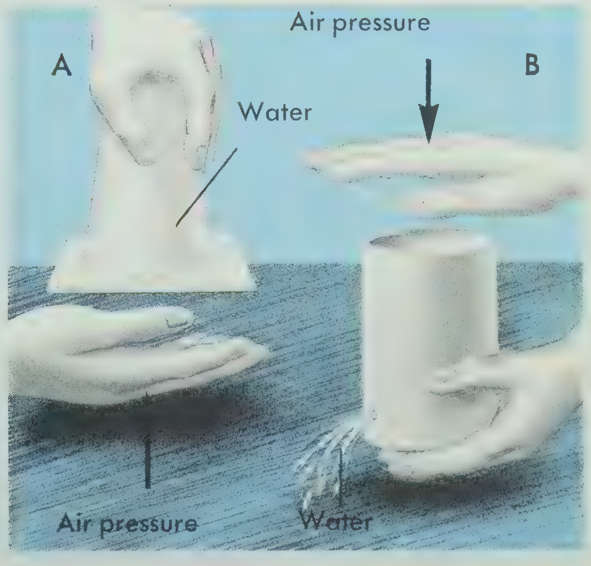


Fig. 25–3

Air pressure holds the flat plate to the glass.

In Fig. 25—3 B, we punched a hole with a nail near the bottom of the can. Holding your finger over the hole, fill the can with water. Cover the open top of the can with your other hand. Take your finger away. Does water come out of the can? Now you lift your palm away. What happens? Of course! The atmosphere is now pushing down on the surface of the water. The water is pushed out of the hole.

6. WHAT CAUSES AIR PRESSURE?

Just as a mass of water caused water pressure, a mass of air causes air pressure. Billions of air molecules are moving about in the atmosphere and are being held around the earth by the force of gravity. These molecules bounce about and strike all surfaces. When molecules strike a surface they exert a force (a push or a pull); it is this force exerted per unit area of a surface which we call pressure. Therefore, air pressure is the result of the billions of molecules in the atmosphere striking against surfaces.

7. HOW DO WE FIGURE AIR PRESSURE?

Pressure is the amount of force pushing against a unit area of a surface. Surface is measured in square metres (m^2). REMINDER: one square metre (m^2) measures a surface 1 m long and 1 m wide.

FORCE is measured in newtons (N). To help you understand how much force is measured as 1 N, think of a D-cell battery resting on your palm. The battery is pulled down on your hand by gravity with a force of about 1 N.

The force exerted by all the air molecules above one square metre on the earth's surface (at sea level) is about 100 000 N. Therefore, air pressure is about 100 000 N/m^2 (newtons per square metre). The unit, newtons per square metre, is called a PASCAL (pas-KEL), (Pa). So, we can refer to air pressure at sea level as about 100 000 Pa. Because this number is so large, scientists normally use the kilopascal (kPa) to refer to air pres-

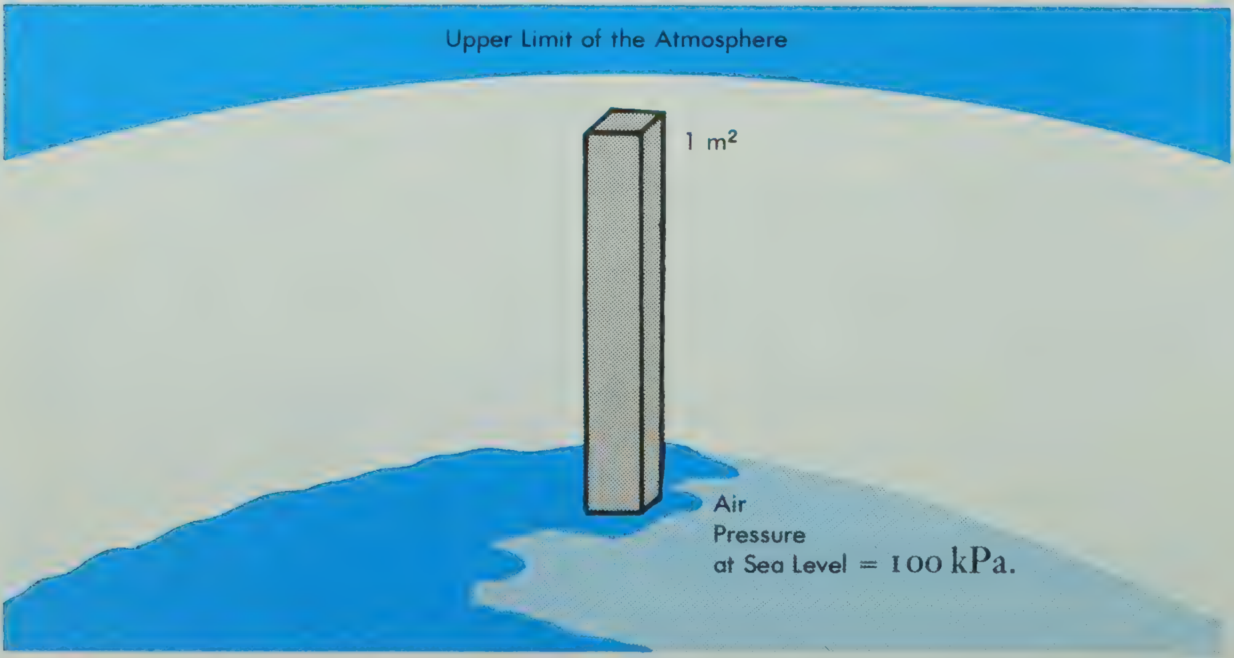

Upper Limit of the Atmosphere
1 m^2
Air Pressure at Sea Level = 100 kPa.

Fig. 26—1

sure (1000 Pa = 1 kPa). Normal air pressure then is $\frac{100\,000}{1000}$ Pa = 100 kPa.

Note: equation

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Total Force} = \text{Pressure} \times \text{Total Area}$$

Air pressure on earth is about the same as a 10-N force pressing on an area of 1 cm². Would you like to know how much force the air is exerting on the cover of your book? With your book closed on your desk, measure the length and width of the cover to the nearest centimetre. Use these numbers to find the surface area in square centimetres. You know that the air pressure is about 10 N/cm², so calculate the force of the air on your book's cover. The work and the answer are given at the end of the chapter on page 28.

8. VON GUERICKE'S "SECRET"

The villagers of Magdeburg did not know very much about science. But to you, of course, it is no secret at all. When the Mayor pumped air out of the sphere, there was less air pressure inside the sphere than outside of the sphere. The outside atmospheric pressure pushed the hemispheres tight. Why was it not crushed like the can? Easy! It was made of steel. When he

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 3?

1. Air in the atmosphere exerts pressure.
2. Hemispheres, when closed, contain air.
3. Gravity makes air pressure stronger at the bottom.
4. The mass of the molecules of air causes air pressure.

II. In which paragraph do you find the answer?

1. Why do we need to know area to figure air pressure?
2. Why is the air closer to the earth denser than the air higher up?
3. Why are "empty" cans not crushed by the atmosphere?
4. What is the atmospheric pressure on a beach at the ocean?

III. Knowing What and Why

1. Area needed for measuring air pressure is figured as
   a. length x width in square metres.
   b. length x width in cubic metres.
   c. length x height in cubic metres.
   d. twice the width in cubic metres.
2. If you have two equal sized cans, one containing 10 trillion molecules of air and the other 5 trillion molecules of air,

   a. the one with more air has half as much pressure.
   b. the one with more air has two times as much pressure.
   c. both cans have the same air pressure.
   d. you need more facts to figure air pressure.

3. The Magdeburg Hemispheres are
   a. layers of air above the troposphere.
   b. the water spheres of the earth.
   c. steel half-spheres.
   d. newly discovered.
4. The phrase "100 kPa at sea level" gives you a hint that
   a. air pressure does not work on the high seas.
   b. sea level is not mountain level.
   c. air pressure might be different at levels other than sea level.
   d. gravity disturbs air pressure.

IV. Understanding the Process

1. Look at Fig. 24–1.
   a. What would happen if the rubber stopper was not tight?
   b. Suppose the rubber tube from the pump to the can were cut, what would happen?
   c. Suppose you made a mistake and attached the tube to the other side of the pump, what would happen? Why?
2. In Fig. 25–3, could you turn the glass sideways and still have the cardboard in place? Explain.

V. Answer to the Problem

Force of air on the cover of *Pathways in Science*:

Length of the cover is 23 cm, the width is 16 cm.

Area = length x width; A = 23 cm x 16 cm = 368 cm^2

Since there is a 10-N force on each square centimetre, that means there will be 10 x 368 or a 3680-N force on the cover…a lot of tennis balls!

VI. Unscramble the letters. Read the first letter down. Get a kind of car.

1. E L U H I M (gas discovered in the sun)
2. Y G X O E N (21% of the air closest to earth)
3. E O P O E R T S P H R (layer of air closest to earth)
4. D M A R I U (from uranium to ____ to lead)
5. T R B O I (path around the sun)
6. I X E D I O D (second part of CO_2)

1. _ _ _ _ _ _
2. _ _ _ _ _ _
3. _ _ _ _ _ _ _ _ _ _ _
4. _ _ _ _ _ _
6. _ _ _ _ _ _ _

VII. A PROBLEM

What is the air pressure on the floor of your classroom? To find out, measure the length of your classroom in metres. Use "round" numbers, no fractions. If, for example, your classroom is 9.4 m long and 6.25 m wide round the numbers off to 9 m and 6 m. The area of your classroom, then, is 9 m × 6 m = 54 m^2. Area = Length × Width.

The air pressure is 100 000 N × 54 m^2 = 5 400 000 N/m^2 or 5400 kPa.

VIII. For The Amateur Scientist

Obtain a can and stopper like the one in Fig. 24–1. CAUTION: Be sure it is washed clean of the material which was in it. (Example: kerosene)

Place about 3 cm of water at the bottom of the can. Heat the can with *the cover off* over a gentle flame. When the water boils and steam comes out, remove the can from the flame *quickly*. Screw the cover on quickly. (CAUTION: Use gloves) Hold the can under cold running water.

1. What happens?
2. Explain why this happened.

4

TARGET
Is air pressure the same all over?

How We Measure Air Pressure

1. A TEACHER GIVES AN ASSIGNMENT TO HIS PUPIL

In 1642, Galileo (gal-i-LAY-o) was a teacher at the University of Pisa in Italy. This great scientist wanted to solve many problems. One of these was why a water pump could never raise water from a well more than 10 m deep. Galileo was than 77 years old and a little blind. He suggested this problem to one of his brilliant young pupils, Torricelli (tor-i-CHEL-ee). Toricelli got an answer. But Galileo had died by that time. Let us follow this great idea.

Fig. 29–1

Evangelista Torricelli developed the mercurial barometer.

2. TORRICELLI DOES AN EXPERIMENT

Instead of working with water, Torricelli decided to work with mercury. Mercury is 13.6 times more dense than water. Therefore, Torricelli only needed a tube about 13.6 times shorter than a 10-m well. This tube would only need to be about 0.80 m or 80 cm long. Your teacher will perform a demonstration very much like the one Torricelli did.

NOTE: Mercury is a dangerous liquid and should not be allowed to come in contact with skin or clothing. Proper ventilation must be used to prevent inhalation of mercury vapours. Check your school board's regulation regarding experimental demonstrations with mercury.

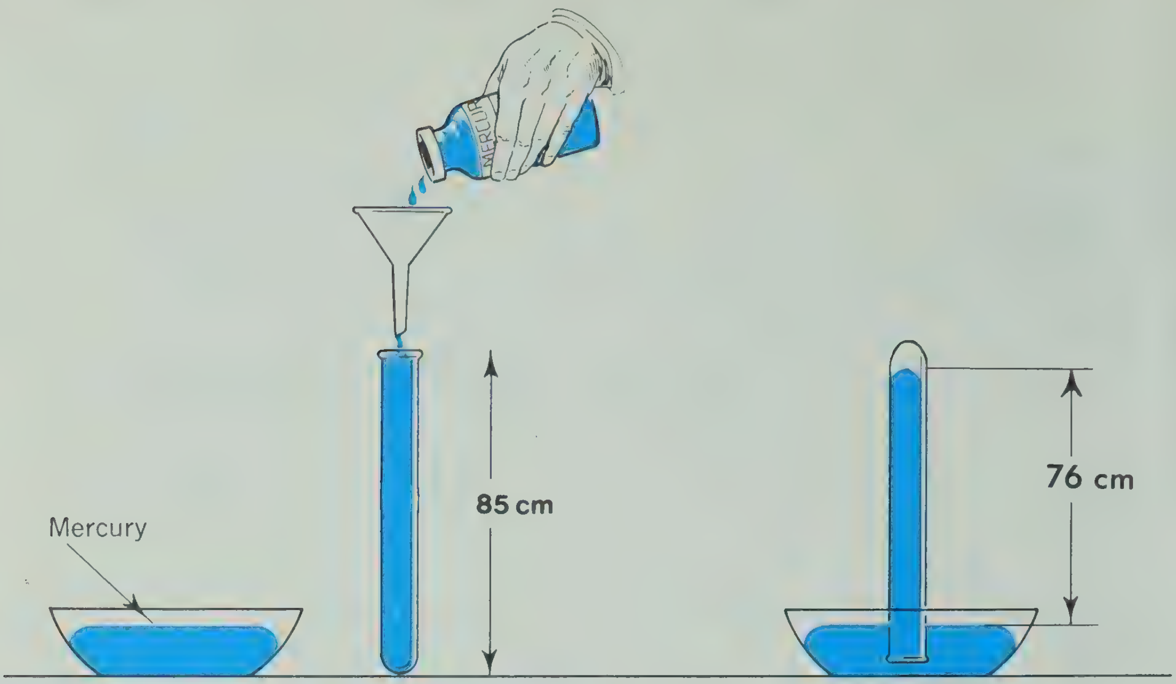


Fig. 30–1

DO AND DISCOVER

(TEACHER DEMONSTRATION)

Investigation 4: How can air pressure be measured?

What to do:

1. Pour some mercury into a shallow dish.
2. Fill a closed-end tube with mercury liquid (have it ready before class).
3. Holding one finger protected by a rubber or plastic glove over the open end, turn the tube upside down. One finger is left on this end until the tube is below the surface of the mercury in the dish.

What you see:

No matter how many times you do it, the mercury will drop in the tube until it stands about 76 cm (0.76 m) above the surface of the mercury in the dish.

What Torricelli learned:

The pressure in the atmosphere presses down on the surface of the mercury with a force strong enough to keep the mercury at a height of 76 cm.

YOU NOW KNOW

- The pressure of the air is about 100 kPa at sea level.
- Air pressure can keep a column of mercury at a height of about 76 cm at sea level.

3. AN ANSWER FOR GALILEO

With this same experiment, Torricelli could have told Galileo why the well could not raise the water more than 10 m.

Mercury, you may remember, is 13.6 times more dense than water. Suppose that Torricelli had used water in the tube. The tube would have had to be 13.6 times longer and the water would have stayed at about the 10 m level. See Fig. 31-1. For water to rise higher than 10 m a special pump would be needed.

4. A NEW INSTRUMENT IS BORN

With this experiment, Torricelli got an answer to one of his questions: "How can we measure air pressure?" The answer is, "With a column of mercury." In this experiment a new scientific tool was born. It is the BAROMETER (buh-ROM-e-tur), (baro

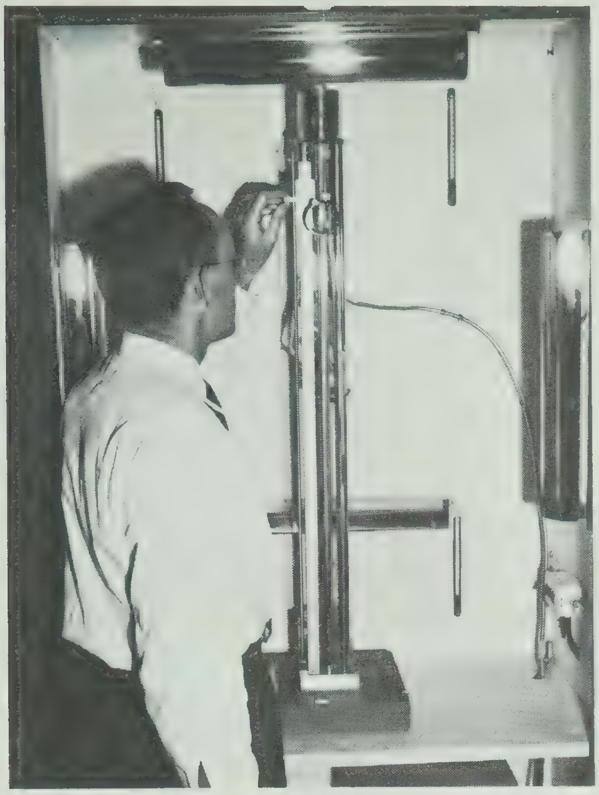


Fig. 31–1

A modern mercury barometer.

= pressure; meter = to measure). When air pressure gets greater, it pushes down harder on the mercury; the mercury is pushed up the tube higher than 76 cm. When the pressure becomes less, the mercury falls below 76 cm. This instrument is called the mercury barometer.

5. BAROMETERS WITHOUT LIQUID

The mercury barometer is large and clumsy. It can break and spill deadly poisonous mercury. Another type of barometer is the one which makes use of an "empty" drum with a needle. A clock-type face then reads the air pressure. This is called the ANEROID (AN-uh-roid) barometer which means without liquid. At the end of the chapter, page 34, you will find a home experiment. It will tell you how to make such a barometer.

6. PRESSURE ABOVE—PRESSURE BELOW

In Chapter 1 we learned that air is less dense high above the earth's surface. Therefore, there are fewer molecules exerting less force: air pres-

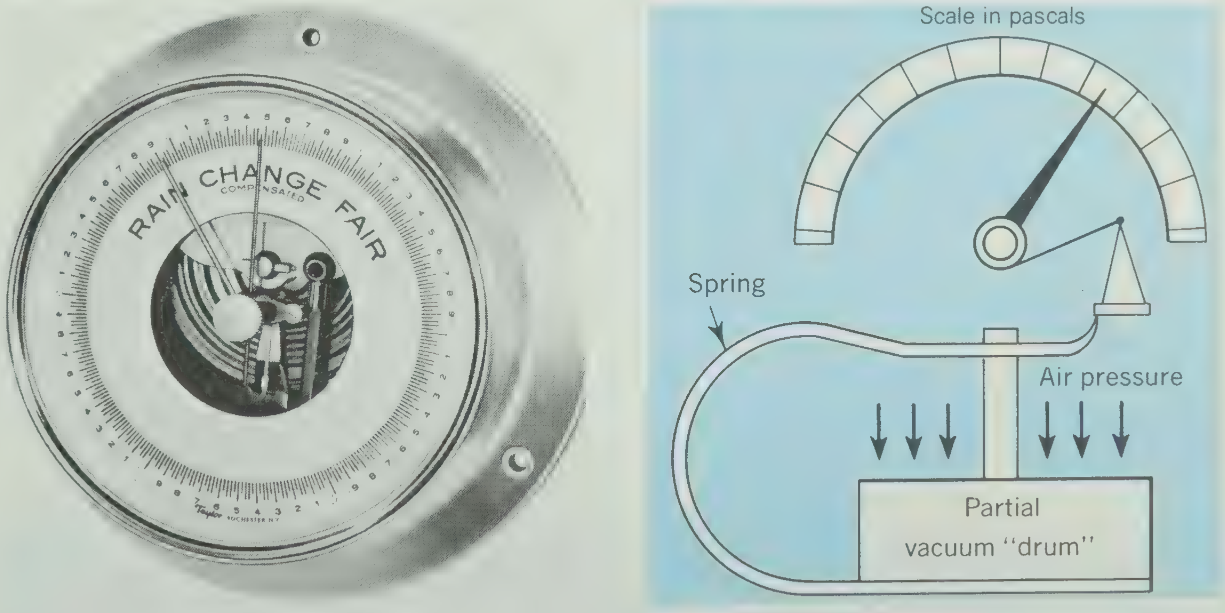


Fig. 31–2

The aneroid barometer is convenient and easy to handle. Where does the air exert its pressure?

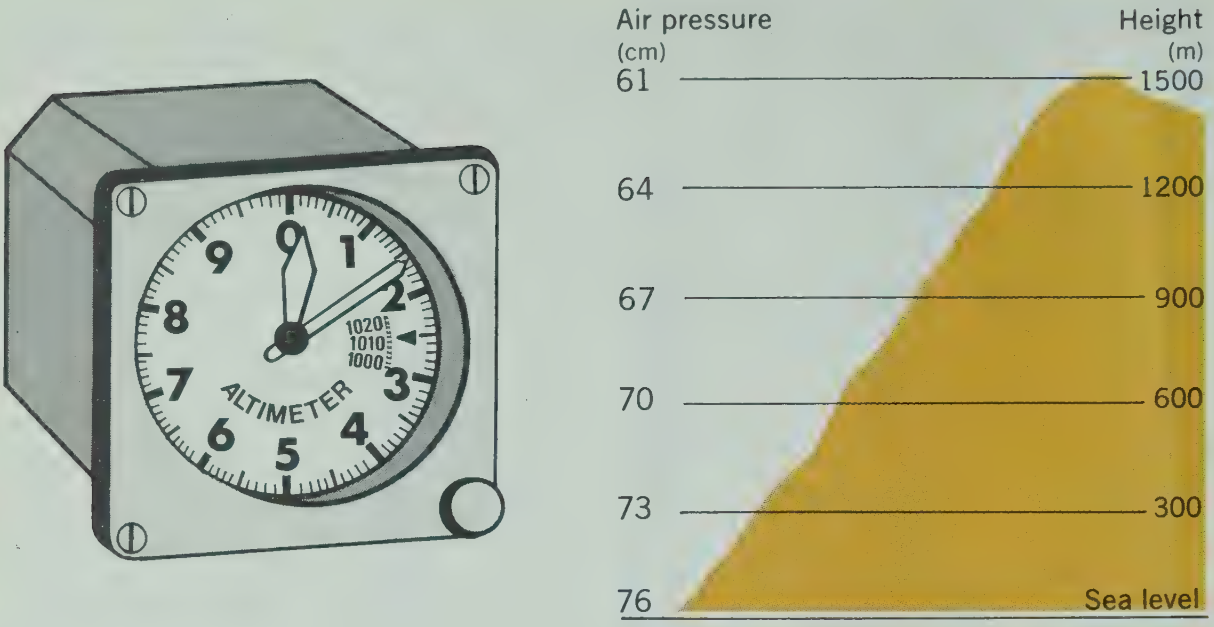


Fig. 32–1

For every 100 m we go above sea level, the barometer drops about 1 cm. What is the elevation in your home town?

sure should be lower as we climb high up a mountain. Soon after Torricelli's experiment, other scientists checked this idea. They carried barometers to mountain tops. Sure enough, the pressure went below 76 cm of mercury. How much below? About 1 cm of mercury for every 100 m. When you take a barometer down a mine shaft, the opposite takes place. The air is now more dense and offers more force. The pressure rises about 1 cm above 76 for every 100 m you go down.

7. MOUNTAIN CLIMBERS AND AVIATORS

Air pressure is 100 kPa only at sea level. Since we know that air pressure drops about 1 cm for each 100 m we go above sea level, and rises 1 cm for every 100 m below sea level, we can find out how far above or below sea level we actually are. If our barometer reads 79 cm of mercury (104 kPa)–3 cm below normal—we must be 3 x 100 m below sea level. So you see that the barometer can be used to measure heights (altitude). Such an aneroid barometer is called an ALTIMETER (al-TIM-e-tur). Its face is marked off in metres so that we do not have to multiply to get our actual altitude. The Dead Sea in Israel is 400 m below sea level. Can you figure out the barometer reading at the Dead Sea? Check your answer at the end of this chapter.

Air Pressure	Above Sea Level	less than 100 kPa	=	less than 76 cm of mercury
	At Sea Level	100 kPa		or 76 cm of mercury
	Below Sea Level	more than 100 kPa	=	more than 76 cm of mercury

YOU NOW KNOW

- ▶ Air pressure is measured with reference to sea level at 100 kPa or 76 cm of mercury on the barometer.
- ▶ As you rise above sea level, pressure decreases. Below sea level, pressure increases above the standard.
- ▶ Aneroid barometers and altimeters do not use mercury.
- ▶ Mercury is a dangerous and poisonous liquid.

8. KILOPASCALS AND BAROMETER READINGS

Normal air pressure, as you remember, is about 100 kPa. We can also say that normal air pressure is about 76 cm of mercury in a barometer. Therefore, we can mark our barometer with the unit kilopascal. Figure 33-1 shows how this can be done. You will notice that there are 4 kPa for every 3 cm of mercury.

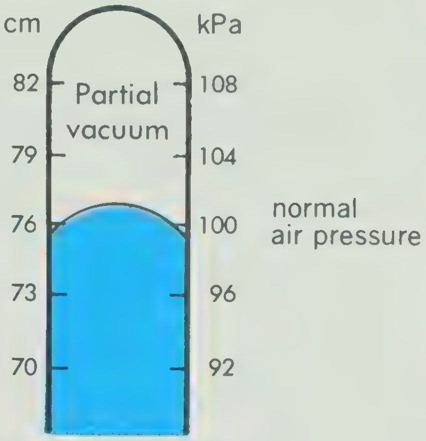


Fig. 33 – 1

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 4?

1. Air pressure is measured indirectly with a barometer.
2. Torricelli invented the first aneroid barometer.
3. There are spots in the world below sea level.
4. Air pressure decreases with altitude.

II. In which paragraph do you find the answer?

1. What will a barometer show below sea level?
2. How does air pressure depend on the density of the atmosphere?
3. What units of measurement are used in an altimeter?
4. What is an aneroid barometer?

III. Knowing What and Why

1. Mercury will be pushed by air pressure to a lower height than water because mercury
   a. is a metal.
   b. is a solid.
   c. has larger molecules.
   d. is more dense than water.
2. The space above the mercury in figure 33–1 is
   a. filled with air.
   b. filled with water.
   c. a partial vacuum.
   d. not a space, it is a reflection of the mercury.
3. An altimeter is most like a
   a. thermograph.
   b. barometer.
   c. metre stick.
   d. kilometre.

4. At sea level, the barometer reads
   a. 10 cm.
   b. 100 cm.
   c. 76 cm.
   d. 1 cm.

IV. True or False? Explain your answer.

1. Water wells deeper than 100 m need a motorized pump to draw the water up.
2. At the Dead Sea, a barometer stops working altogether.
3. You cannot take a mercury barometer to the top of Mount Everest.
4. When the radio announcer says, "The barometer is falling," he means the reading must go below 100 kPa.

V. The Science Reporter

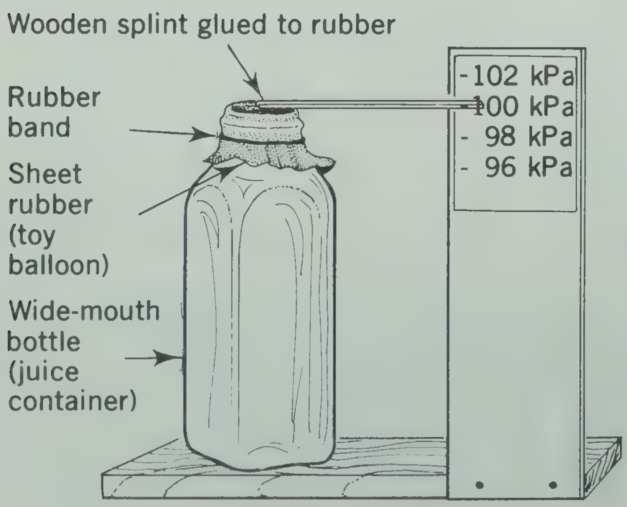
Read the story and life of BLAISE PASCAL, the French scientist. Report on his work with barometers.

VI. Answer to the Problem

Look at Paragraph 7.
The Dead Sea is 400 m below sea level.
The barometer rises 1 cm for each 100 m you go below sea level.
400 m = 4 cm of mercury
Therefore the barometer reading is normal + 4 cm of mercury or 80 cm of mercury.

VII. For the Home Scientist

Make a simple aneroid barometer.
Follow the diagram below.


Wooden splint glued to rubber
Rubber band
Sheet rubber (toy balloon)
Wide-mouth bottle (juice container)
-102 kPa
-100 kPa
- 98 kPa
- 96 kPa

VIII. For The Aviation Buff.

Read about airplanes in an encyclopedia. Prepare a report for the class. Use the following guidelines.

1. At what altitudes do modern planes fly?
2. What is the atmospheric pressure at such altitudes?
3. Why is the passenger cabin pressurized? How is this done?
4. What happens if the cabin pressure begins to drop?

IX. Go and Discover

1. Visit a gas station. Find out the difference between tube tires and tubeless tires. What is the advantage of a tubeless tire?
2. Visit a department store. Examine the barometers on sale. What are the lowest and highest readings on their scales? What are the prices of several kinds of barometers?

5

TARGET
How can we use our knowledge of air pressure?

Air Pressure Goes to Work

1. LOOKING BACK . . .

At sea level, air pressure is 100 kPa. So the barometer reading is about 100. When air is more dense (more molecules), pressure is greater. When air is less dense (fewer molecules), pressure is reduced. If we remove all molecules of air, pressure is reduced to zero. We then have a VACUUM (VAK-you-um).

2. AIR CAN BE SQUEEZED TOGETHER

DO AND DISCOVER

Investigation 5: Can we compress air?

Turn the empty bottle upside down in the water in the large jar. The water does not enter the bottle because the air pressure inside keeps it out. Now, holding the bottle straight, force it downward. The water rises in the bottle. The air in

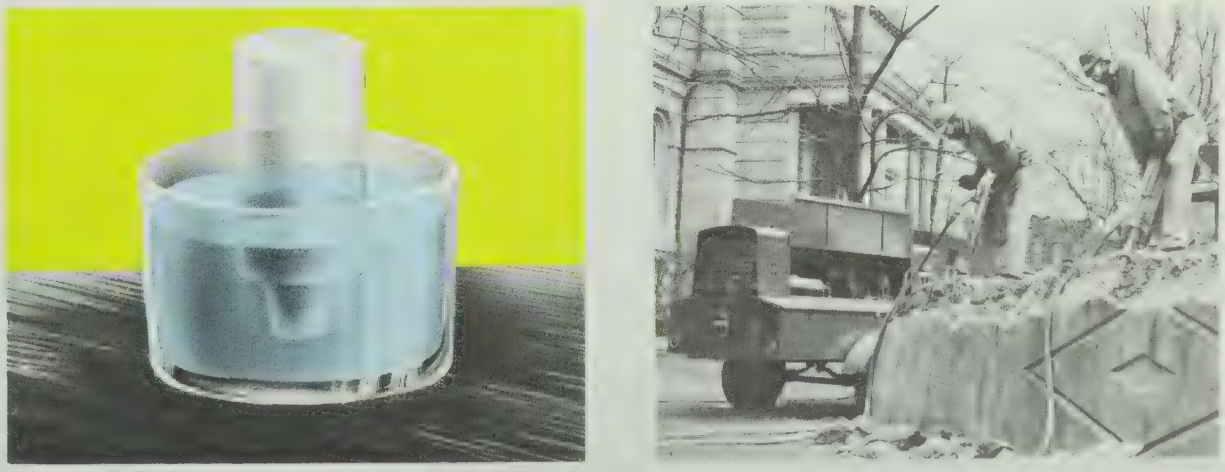


Fig. 35–1

When you force the bottle down, the air is compressed. The compressor at the right is a machine that squeezes air into a tank.

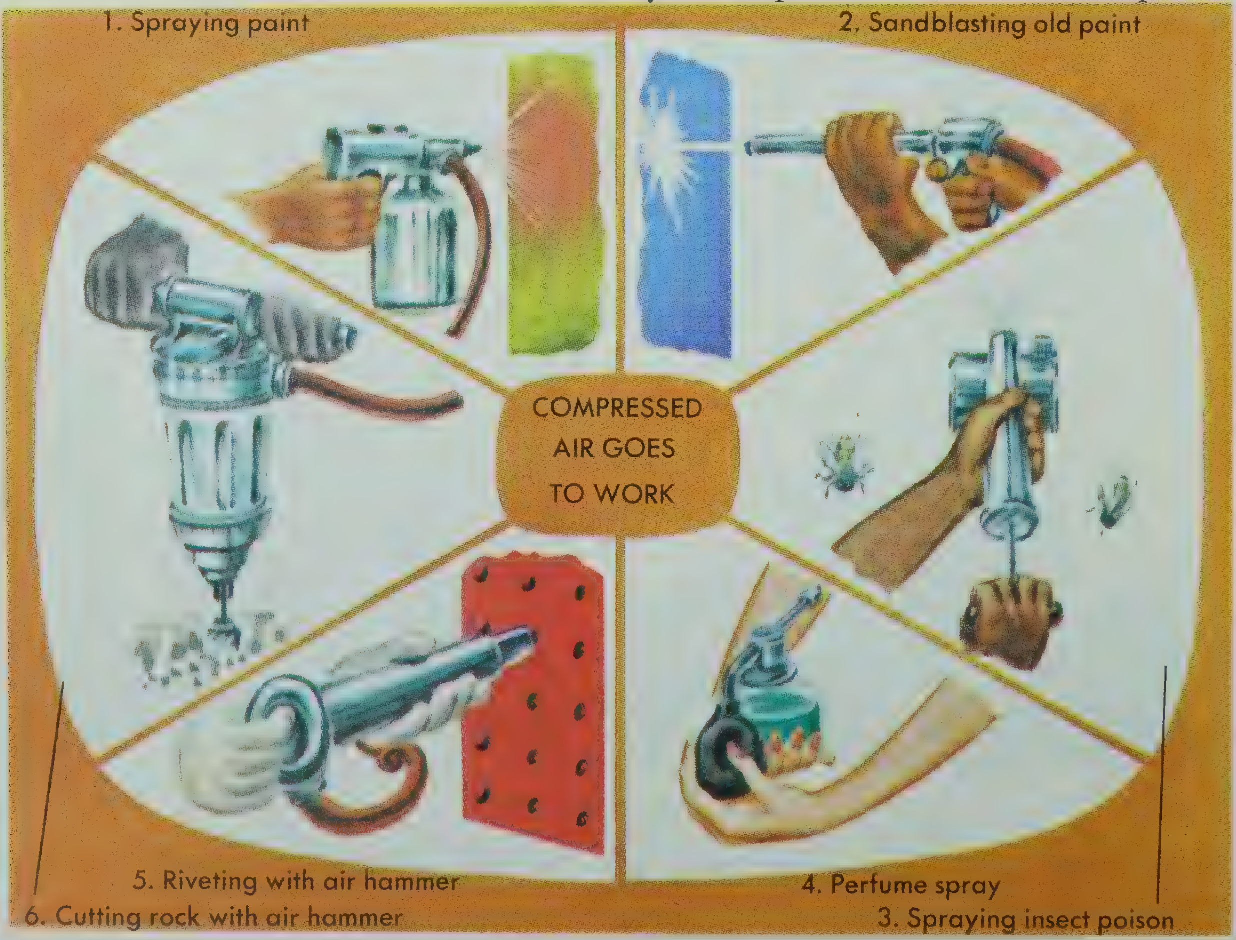
the bottle has been squeezed into a smaller space.

Squeezed air is called COMPRESSED (kom-PREST) air. Air can be compressed to produce pressure far greater than 100 kPa. It can be compressed to be 200, 400 or even 800 kPa. Of course, air under this pressure has terrific power. Compressed air is therefore used to do work. Let us see how.

3. COMPRESSED AIR GOES TO WORK

You have seen compressed air at work many times. A common sight at a gas station is the checking of air pressure of tires. Tire tubes are filled with air to reach pressures of between 130 to 200 kPa. The tire is blown up; the car can then ride on a soft "cushion" of air to absorb shocks when the tires go over bumps.

How is a submarine brought to the surface? The commander orders compressed air to force the water out of the ballast tanks. Have you seen the sign on the backs of trucks, "*Danger—Air Brakes*"? These giant trucks carry tanks of compressed air which operate their brakes. These work quickly. The sign is a warning to drivers not to stay too close. Buses and subway cars use compressed air to open and shut the doors. The "hiss" you hear is the release of air. You may have heard the same sound on some heavy doors. These doors are kept from slamming by a door check which uses compressed air. The pictures below will show you some other jobs that compressed air can do. Can you explain why modern planes


1. Spraying paint
2. Sandblasting old paint
COMPRESSED AIR GOES TO WORK
5. Riveting with air hammer
6. Cutting rock with air hammer
4. Perfume spray
3. Spraying insect poison

which fly at high altitude "pressurize" their cabins?

4. REDUCED AIR PRESSURE

If we reduce the number of molecules of air in a closed space, the air that is left weighs less than before. Therefore, the air pressure is now less. Look at Fig. 37-1. When you suck air out of the tube, the pressure in the funnel goes down. The atmospheric pressure pushes in the rubber sheet. If you blow air in, you are increasing the pressure. The rubber sheet goes out. It becomes like an "Indian arm wrestle." The greater pressure pushes the weaker pressure back.

YOU NOW KNOW

- Compressed air pressure results from squeezed air which is denser (more molecules) and heavier than atmospheric air.
- Reduced air pressure results from "spread out" air which is less dense (fewer molecules) and lighter than atmospheric air.
- Air pressure exerts force from the greater pressure to lesser pressure.

5. AIR PRESSURE AND BREATHING

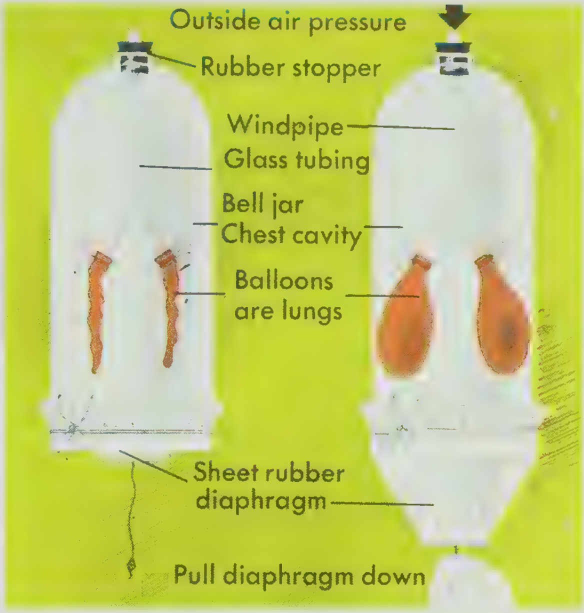


Fig. 37–2

Use this diagram to explain how reduced air pressure helps us to breathe.

In the human breathing system, inhaling brings the ribs up and out. This enlarges the chest cavity. At the same time, the DIAPHRAGM (DY-a-fram) goes down. Again, this enlarges the chest cavity. Enlarging the chest cavity means that the air spreads out, becoming less dense. The air pressure is reduced. The atmospheric air pressure is still 100 kPa, and pushes the air

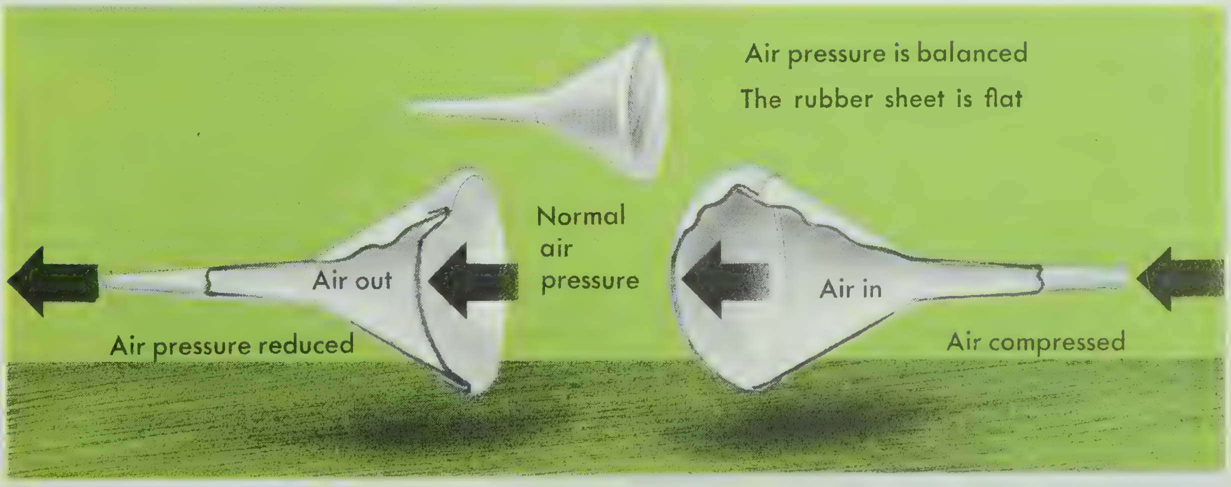


Fig. 37–1

In which direction does the air usually flow?

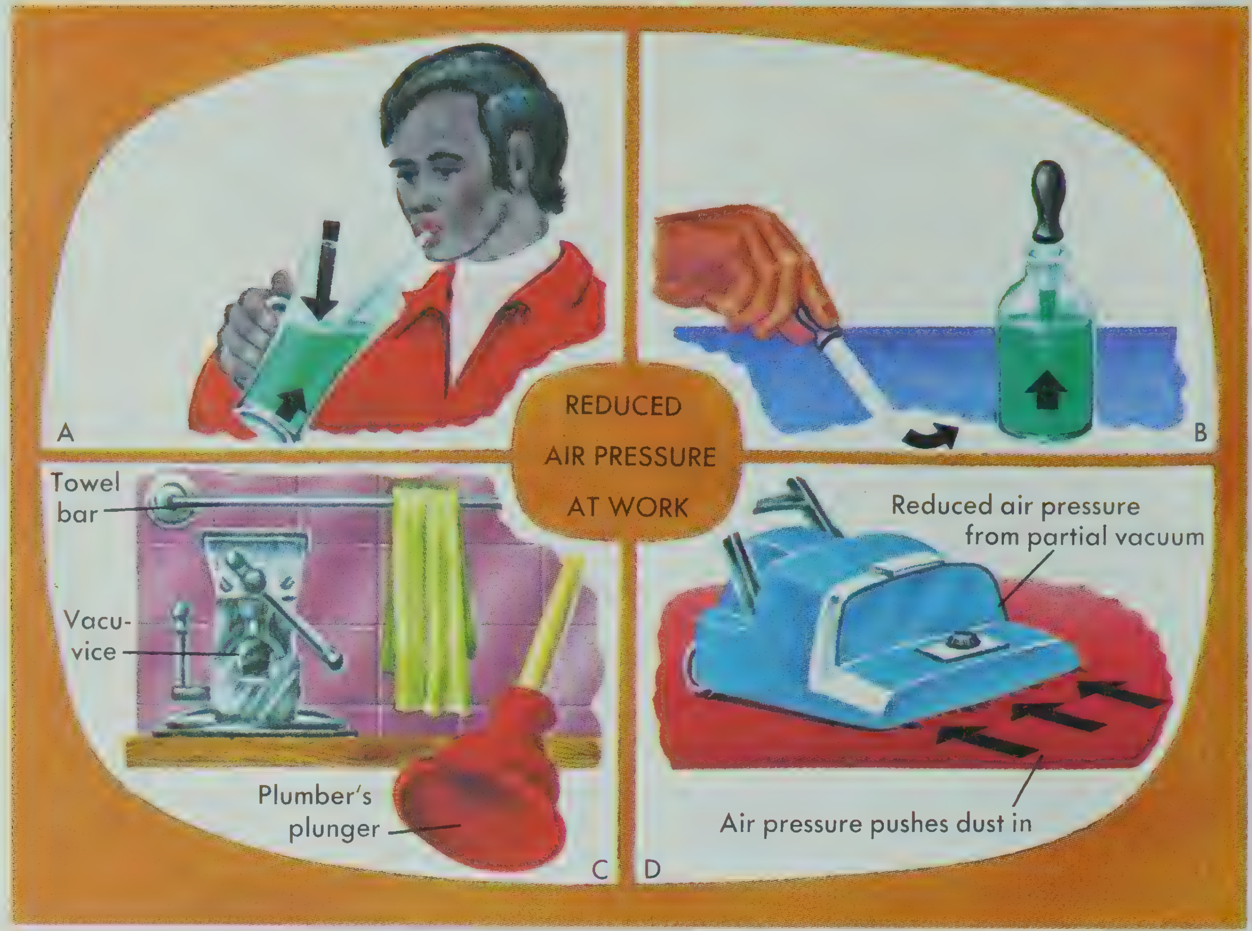

A
B
REDUCED AIR PRESSURE AT WORK
Towel bar
Vacu-vice
Plumber's plunger
C
D
Reduced air pressure from partial vacuum
Air pressure pushes dust in

Fig. 38–1

Each device uses reduced air pressure.

in through the nostrils. Now can you tell why it is harder to breathe on a mountaintop? You are right. The air is less dense; the pressure has dropped. Air cannot be pushed into your nostrils quite as easily.

6. REDUCED AIR PRESSURE IN THE HOME

Many devices in our homes depend on reducing air pressure and then letting the atmosphere do the work. Did you know that you drink a soda with the help of the atmosphere? Did you know that your medicine dropper works the same way? Look at Fig. 38-1 and you will quickly get the idea.

The motor in a vacuum cleaner "sucks" air out of the tank. Atmospheric pressure pushes the dust in. Do you recognize the towel holder and the plumber's plunger? Each of these uses rubber suction cups. Squeezing the cup reduces the air pressure inside. Atmospheric pressure then does the work.

7. LET'S EMPTY THE FISH TANK

Larry has a fish tank that holds 80 L of water. He wants to empty it. Shall he lift it? It's quite heavy. In fact, he knows that the water alone weighs 80 kg. (Each litre weighs about 1 kg. Total mass = 80 kg.) But Larry has learned to empty the tank by using a SIPHON (SY-fun). Let's see how he did it.

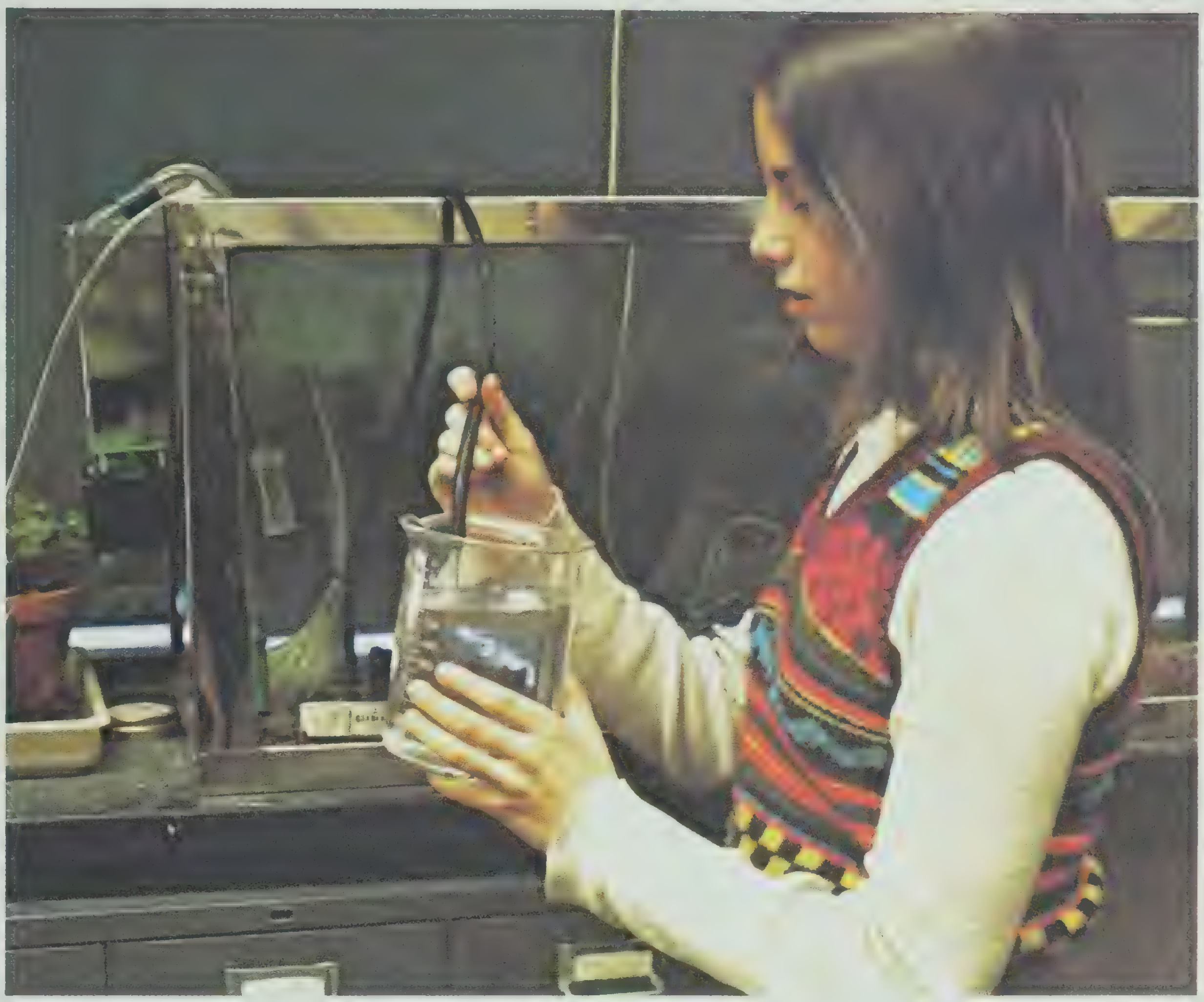


Fig. 39–1

You can empty a fish tank by using a siphon. After this jar is full, the girl will empty it into a larger pan on the floor.

First, Larry got a rubber tube, long enough to reach from the tank to the pail. Then he poured water into the tube to the very top of each end. As he poured the water in, what happened to the air? Right! It was pushed out. Now, holding one finger over each end, he dropped one end below the water level in the tank. Then he lowered the other end into the pail. The water began to flow quickly. Why? The atmospheric pressure on the surface of the water *pushes* the water through the tube. When the pail was almost filled, Larry raised the tube. He emptied the pail into the sink. Then he repeated the job a few more times until the tank was empty.

YOU NOW KNOW

- Breathing depends on air pressure in the chest.
- Many household devices work by reduced air pressure.
- Siphons work by reduced air pressure.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 5?

1. Air brakes use compressed air.
2. Air can be compressed to increase pressure, or spread out to reduce pressure.
3. Reduced air pressure is used by plumbers.
4. Stronger air pressure can exert force against weaker air pressure.

II. Explanation, please . . . answer in one or two sentences.

1. What pressure in kilopascals is called compressed? Why?
2. How does sandblasting use air pressure?
3. Why is it hard to breathe at the top of Mt. Everest?
4. How does a siphon work?

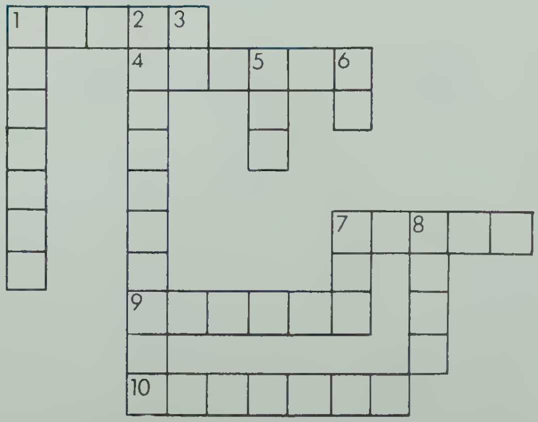
III. Knowing What and Why

1. The air pressure in a medicine dropper is
   - a. first reduced.
   - b. compressed.
   - c. neutralized.
   - d. siphoned out.
2. When the diaphragm in the human chest moves up, it causes
   - a. the ribs to go up.
   - b. air molecules to spread out.
   - c. respiration.
   - d. oxygen to be compressed in the lungs.
3. Compressed air brakes
   - a. exert great force to stop a truck.
   - b. reduce friction against the tires.
   - c. spread molecules of air against the tires.
   - d. reduce air pressure in the carburetor.
4. Air pressure in the tire tube of a bicycle
   - a. is reduced when you blow air into it.
   - b. increases when a nail makes a hole in it.
   - c. is compressed when you pump air into it.
   - d. acts like brakes in a truck.

IV. Understanding the Diagrams

1. In Fig. 38–1A, where is the greater air pressure?
2. In Fig. 38–1D, what is the job of the motor and fan?
3. In Fig. 38–1C, why would the plunger work better if you smeared vaseline across the rim?
4. In Fig. 35–1, when does the air in the bottle have the greater density? Explain.
5. In Fig. 39–1, what could you do to start the siphon if you did not do the first thing at the left in Fig. 38–1A? Explain.

V. Solve the Puzzle



Across

1. To melt or clear of ice
4. Gaseous element for breathing
7. Instrument used to hold bottles
9. Device used to empty a water tank
10. Amount of matter per unit volume

Down

1. Evaporate and condense
2. Air under high pressure
3. Prefix meaning "out of"
5. Valuable stone in jewelry
6. Symbol for nickel
7. _____ millimetres = one centimetre
8. Gaseous element that glows red

VI. For the Home Scientist

Repeat the experiment in Fig. 39–1. Fill a washbasin with water. Use a pail and a rubber tube or a short piece of garden hose.

VII. For The Science Reporter

In an encyclopedia, read the section on tunnel building under water.

1. What is the idea behind building a tunnel under water?
2. What is a *caisson?*
3. What are *sandhogs?*
4. What are the *bends?*
5. What is the usual pressure in a caisson?

6

TARGET
How does the atmosphere get its heat?

Most of The Earth's Heat Comes from the Sun

1. THE SUN IS A BALL OF VERY HOT GASES

At the center of our solar system is a star called the *sun*. It is a ball of very hot gases more than 100 times as big as our earth in diameter. It gives off powerful rays of light in the form of RADIANT (RAY-dee-ant) energy. This energy travels to the earth at a speed of approximately 300 000 km/s in 8.33 min.

The temperature on the surface of the sun is about 5520°C, and much hotter inside. Scientists now believe that the heat of the sun comes from natural atomic energy. In this process, hydrogen is believed to be changed to helium. The mass (matter) is changed to energy (heat).

What happens to this light as it passes through the atmosphere? How much of it reaches the earth? What happens to it once it does reach the earth? Let's find out.

Radiant Sun Energy
- Invisible Heat Waves
- Visible Light Waves
- Invisible Ultra-Violet Rays
- X rays, Gamma Rays, Cosmic Rays

2. WHEN LIGHT STRIKES A MATERIAL

In Fig. 43-1, a flashlight throws light at four different kinds of materials. The mirror sends the light back. The glass lets the light go through. The wood absorbs the light. (It does not allow any light to pass through it.) The water *refracts* or bends the light.

LIGHT ENERGY CAN BE

TAKEN IN:	SENT THROUGH:	BOUNCED BACK:	BENT:
ABSORBED	TRANSMITTED	REFLECTED	REFRACTED

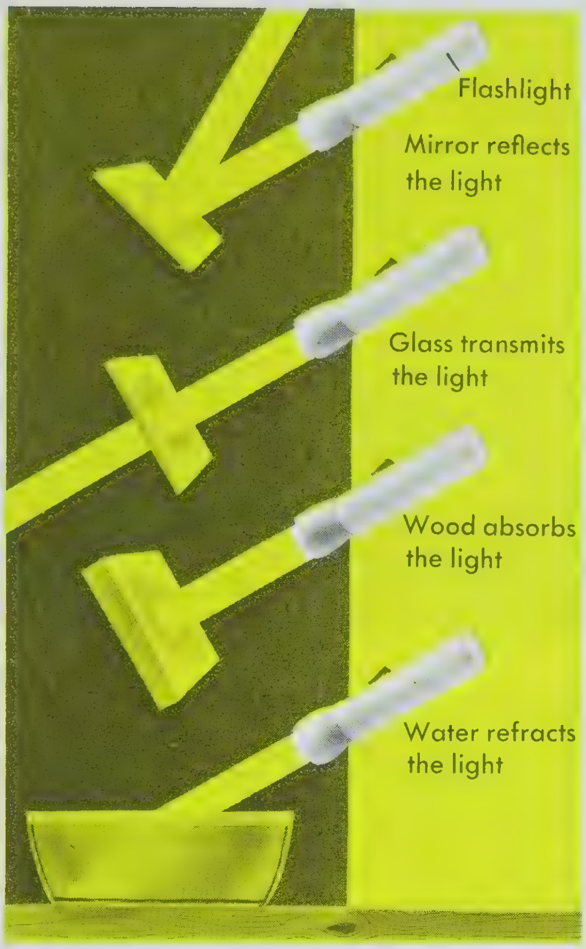


Fig. 43–1

What happens to light when it strikes these materials?

3. ABSORPTION BY LIGHT OBJECTS AND DARK OBJECTS

In Fig. 43-2, the thermometer shows clearly that dark-colored objects absorb heat much faster than light-colored objects. We use this knowledge when we wear dark colored clothes in the wintertime and change to light-colored clothes in the summertime.

4. WHICH HEATS FASTER: SOIL OR WATER?

The temperature of the soil goes up faster than the temperature of the water. (See Fig. 43-3.) However, land also loses its heat faster than water. For example, the beach gets hot early in the day, but the water gets hot much later. In the evening, the beach

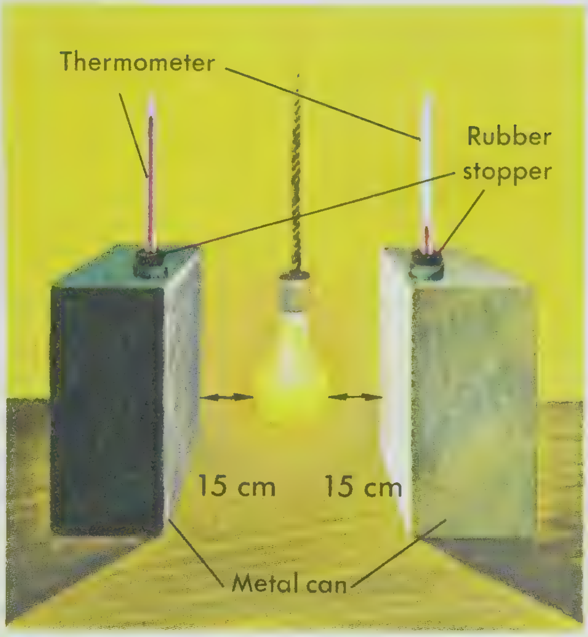


Fig. 43–2

How does this investigation explain why Arabs in the desert wear white robes?

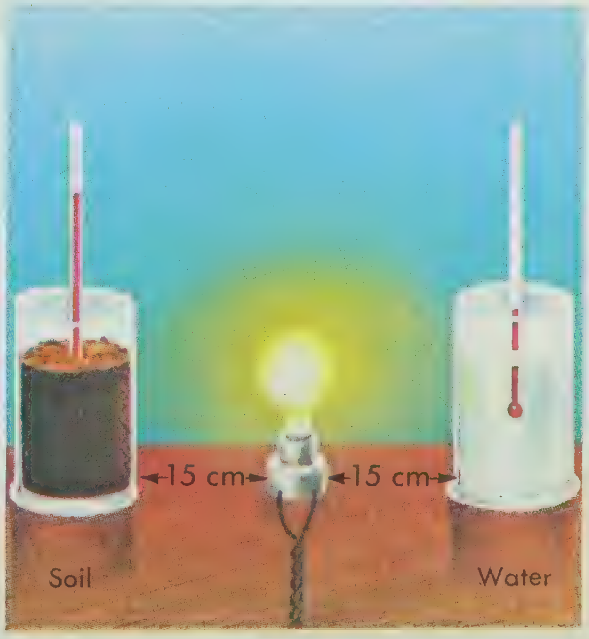


Fig. 43–3

How does this investigation explain why you might swim in the ocean in the evening without feeling chilly in the water?

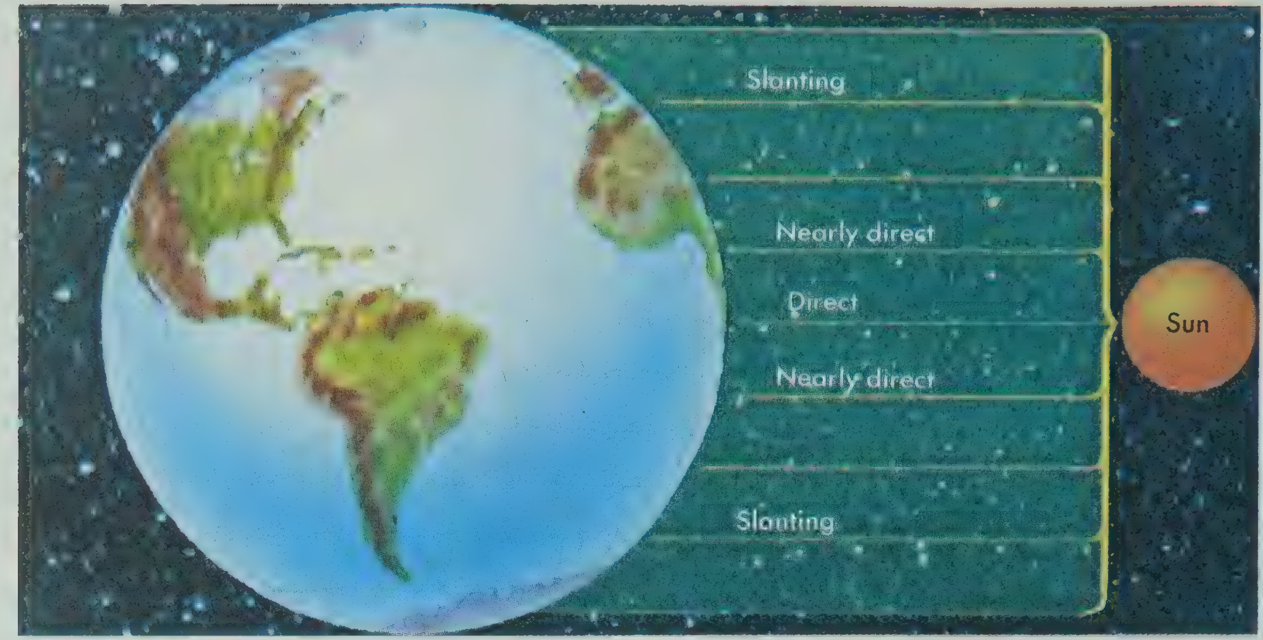


Fig. 44–1

On what dates are the sun's rays direct at the equator?

becomes quite cool, while the water remains warm.

YOU NOW KNOW

- Heat comes to the earth from the sun.
- Radiant energy is either absorbed, transmitted, reflected or refracted.
- Heat energy is absorbed faster by dark-colored surfaces than by light-colored; faster by soil than by water.

5. DIRECT RAYS AND SLANTING RAYS

The amount of heat that reaches the earth from the sun is not the same all over. If you look at Fig. 44-1, you will see that the sun's rays are slanting, nearly direct or direct. As you go from the equator, north or south, towards the poles, the rays are slanting. How does this change the amount of heat?

DO AND DISCOVER

Investigation 6: How does the slanting of sun rays affect heat?

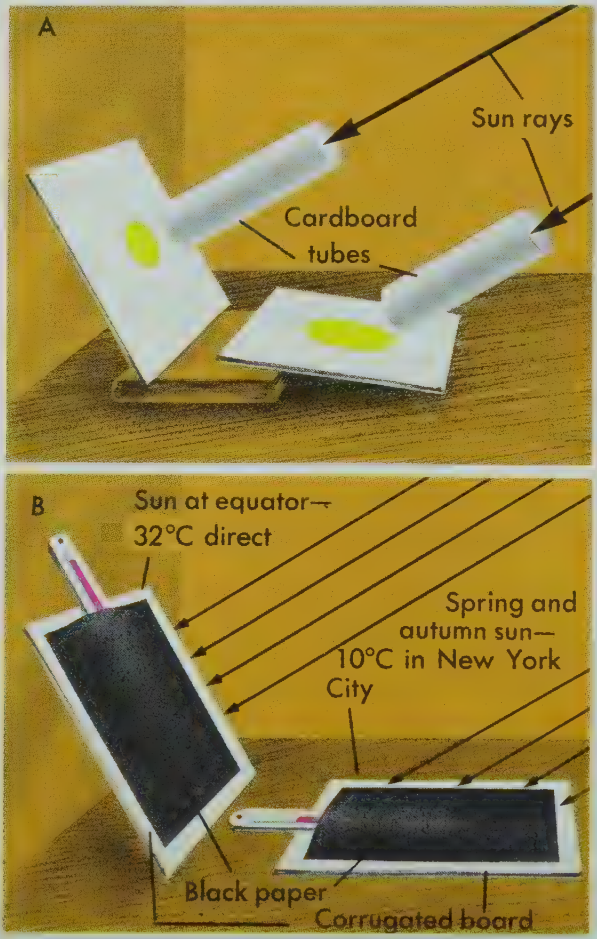

A
Sun rays
Cardboard tubes
B
Sun at equator—32°C direct
Spring and autumn sun—10°C in New York City
Black paper
Corrugated board

Fig. 44–2

What you do:

1. Set up the two experiments as shown in Fig. 44–2.

What you see:

In Fig. 44–2A, the area of light is larger with slanting rays than with direct rays. In Fig. 44–2B, the temperature is higher with the direct rays (left) than with the slanted rays (right).

What you learn:

1. Light falling at a slant covers a wide area. Therefore, its heat is spread out.
2. Light falling on a spread out area gives less heat than direct rays on a smaller area.

You can now understand why it is warmer at the equator than in the northern or southern hemisphere. It is because more direct sun rays reach the equator during the year. Would you be more likely to get a sunburn lying flat on your back or propped up on a back rest? At what time of the day?

6. LET'S VISIT A GREENHOUSE

Have you ever visited a greenhouse and felt the great heat? Or have you ever entered a closed car after it had been standing in the sun for a while? The sun's rays enter the greenhouse and car through the glass, but the heat stays in. Why?

DO AND DISCOVER

Investigation 7: How are light rays changed to heat?

Set up the experiment in Fig. 45–1. Record the readings in your notebook in table form. You will see that the temperature in B rises very little. The temperature in A rises much more and very quickly. Why?

THERMOMETER READINGS

JAR	START	5 min	10 min	15 min	20 min
A					
B					

7. RADIATION OF HEAT BY THE EARTH

We have already seen that sun rays pass quickly through space. Carbon dioxide and water in the atmosphere absorb some of these rays. Scientists have found that less than half (47%) of these rays reach the surface of the

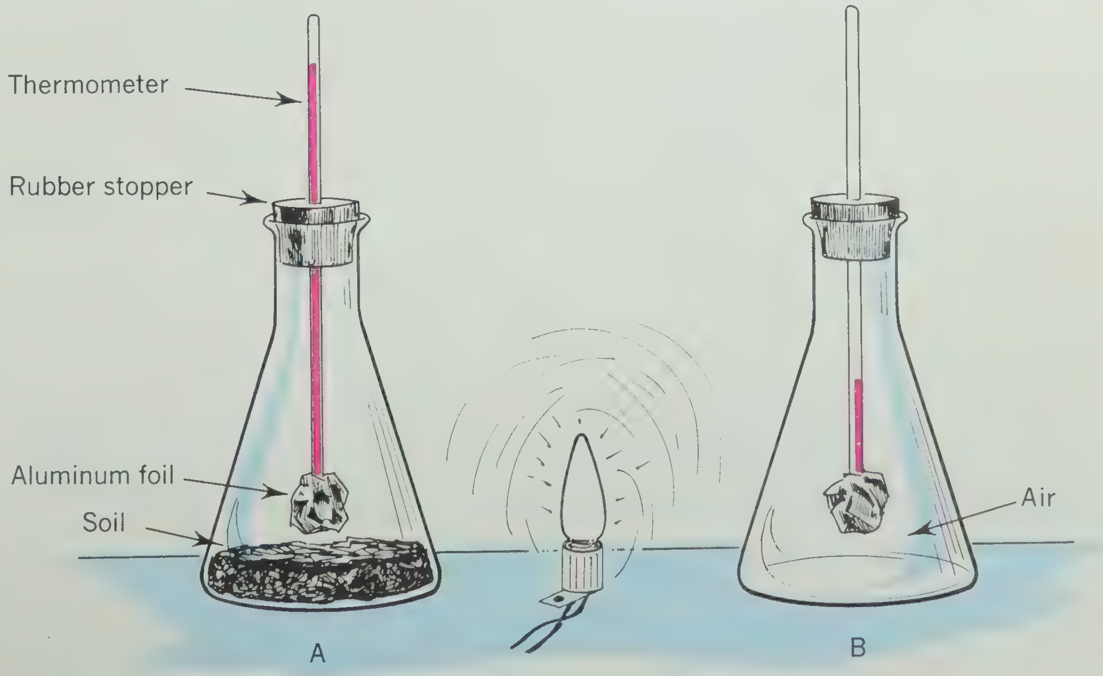


Fig. 45–1

earth (soil, water, plants). An earlier experiment showed you that the light rays are absorbed by the soil and changed to heat. These heat rays cannot pass back through the CO_2, water vapor or clouds. They are trapped above our soil. This is the source of most of our heat. In the greenhouse and in the closed car, short light rays passed through the glass. The soil in the benches or the seat cushions in the car absorb the rays. They are then radiated out into the air in the greenhouse or car as heat rays. Long heat rays cannot pass through the glass. They remain trapped. On a sunny day touch the windowpane; it is cool. Now touch the window sill; it is warm. Can you explain this?

8. CAPTURING THE SUN'S ENERGY

How is the sun's energy captured? First, heat is captured by the earth. Second, green leaves absorb the sun's energy in food-making.

But can we actually use the sun for other forms of energy? If so, we might find a new way to do our work.

Two methods for using *solar energy* have been used with success. One way is to use *solar reflectors* to gather sunlight. The heat rays are then directed at heating water. There are several cities which now heat their water in this way.

Another successful use is to charge *solar batteries*. In these batteries, special cells change light to electricity. Solar batteries have been used in man-made satellites in space. Some telephone companies have used them as a power source.

YOU NOW KNOW

- ► Direct rays of light fall on a smaller area than slanting rays. Therefore, direct rays produce more heat than slanting rays.
- ► Our atmosphere is heated mostly by indirect radiation from the soil.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 6?

1. Radiant energy from the sun is changed to heat on the earth.
2. The earth absorbs heat from the sun and radiates it.
3. It's good to wear white clothes in the summer.
4. Greenhouses develop a great deal of heat.

II. In which paragraph do you find the answer?

1. What happens to heat rays on the earth?
2. Why does a black car in the sun get hotter than a white car?
3. Which part of the earth gets more direct sun rays?
4. Do heat rays from the sun pass through glass?

III. Knowing What and Why

1. At noon, you are more likely to get sunburnt lying down on the beach than propped up on a backrest because
    a. slanting rays are cooler.
    b. you get more wind sitting up.
    c. your face reflects better when you sit up.
    d. it's just chance.
2. Light striking a mirror is
    a. all absorbed.
    b. partly absorbed, partly reflected.
    c. all reflected.
    d. all refracted.
3. The beach seems to grow cool very fast at night because
    a. of condensation.
    b. land radiates heat faster than water.
    c. of the humidity.
    d. of the night winds.

IV. Understanding the Experiments

1. In Fig. 43–3, why must both jars be 15 cm from the lamp?
2. In Fig. 43–3, would it make a difference if the soil were white beach sand? Explain.
3. In Fig. 43–2, how would the thermometers look if both cans were black? If both were white? Explain.
4. In Fig. 44–2, must you use the same tube both times? Explain your answer.

V. Choose the words from *Column B* which best match those in *Column A*.

A

1. radiant energy
2. light turned back
3. direct rays
4. dark objects
5. soda straw
6. twice atmospheric pressure
7. altimeter
8. the Dead Sea

a. reflected
b. equator
c. 200 kPa
d. water level
e. height above sea level
f. absorbs
g. sun
h. 76 cm of mercury
i. below sea level
j. reduced air pressure

VI. For the Home Scientist

Prepare two cans as shown in Fig. 43–2. Paint one black, the other white. Bring them to class. Your teacher will fit the cans with stoppers and thermometers. You will then be able to do the experiment shown in Fig. 43–2.

7

TARGET
Why do temperatures change in the atmosphere?

The Temperature of the Atmosphere Keeps Changing

1. HOW IS WARM AIR DIFFERENT FROM COLD AIR?

DO AND DISCOVER

Investigation 8: What do we know about warm air?

What you do:

1. Balance two equal-sized metal cans (open on top) as shown in Fig. 49–1A.
2. Heat the air in Can 1.
3. Allow time for cooling. Balance carefully.
4. Heat the air in Can 2.

What you see:

1. When the air in Can 1 is heated, the can rises. It is lighter than Can 2 (Fig. 49–1B).
2. When the air in Can 1 is allowed to cool, it is no longer lighter than Can 2.
3. When the air in Can 2 is heated, it is then lighter than Can 1 (Fig. 49–1C).

What you learn:

When the air was heated, it expanded. Its molecules moved apart. Some molecules left the open can. The air was less dense. Warm air weighs less than cold air (Fig. 49–1D).

2. HOW DOES HEAT TRAVEL IN OUR ATMOSPHERE?

Look at Fig. 50-1. The heat of the fire is transferred to the aluminum of the pot. The molecules of the aluminum begin moving rapidly and the metal gets hot. The heat is transferred to the molecules of the wood in the handle. But the molecules of the wood move much more slowly. The wood gets warm, but not hot. The heat is being transferred by the molecules of the matter. This is called CONDUCTION (kon-DUK-shun).

Place your hand on the table beside the Bunsen burner. The air feels cool. Now place your hand about 30 cm above the flame. The air feels warm. The explanation is easy. Fig. 49-2

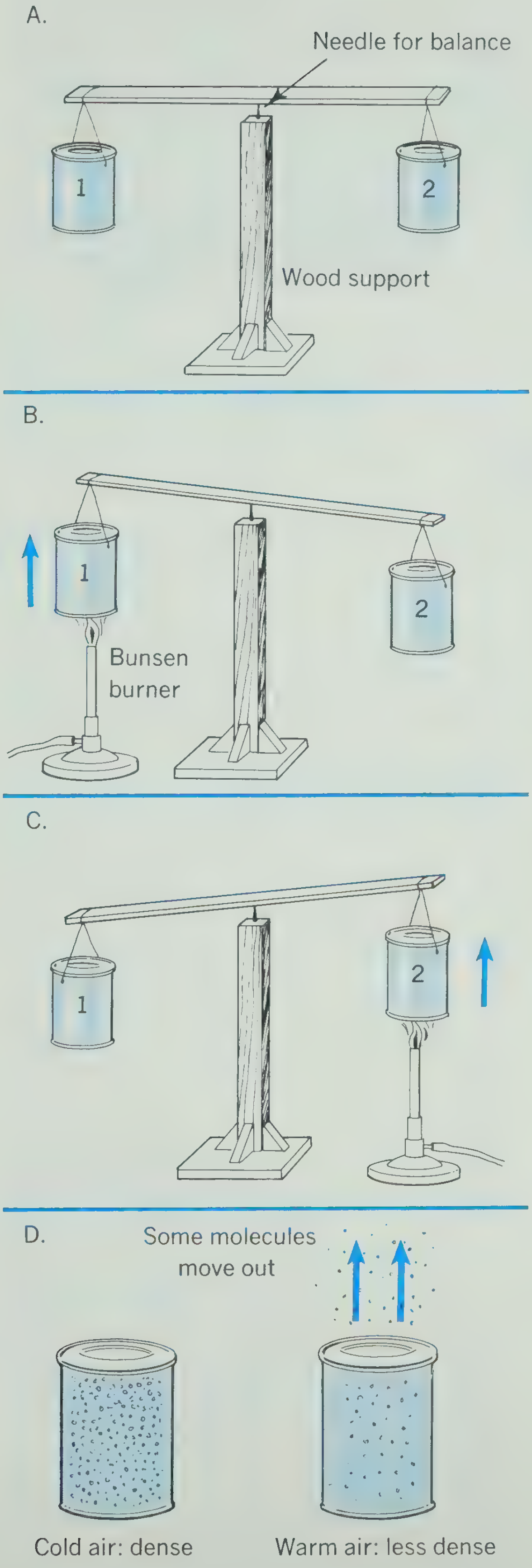


Fig. 49–1

shows a homemade pinwheel over a flame. We know from Paragraph I that the warm air is less dense. It is pushed up by the cold air and spins the wheel. The heat now travels by *moving air* called a CURRENT (KUR-rent). This kind of heat transfer by masses of fluids is called CONVECTION (kon-VEK-shun).

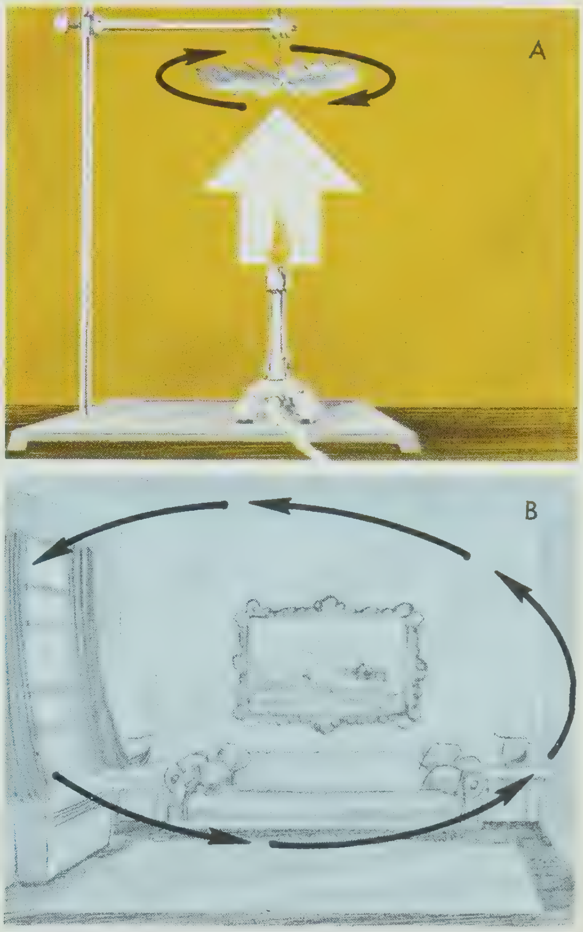


Fig. 49–2

Can you explain what is happening in the room by using the pinwheel as an explanation?

If you hold your hand on the side of a toaster, a lamp or in the sun, the heat is reaching you by RADIATION (ray-dee-AY-shun). In Chapter 6, we saw that the soil and waters of the earth absorb sun-energy and radiate it into the atmosphere as heat.

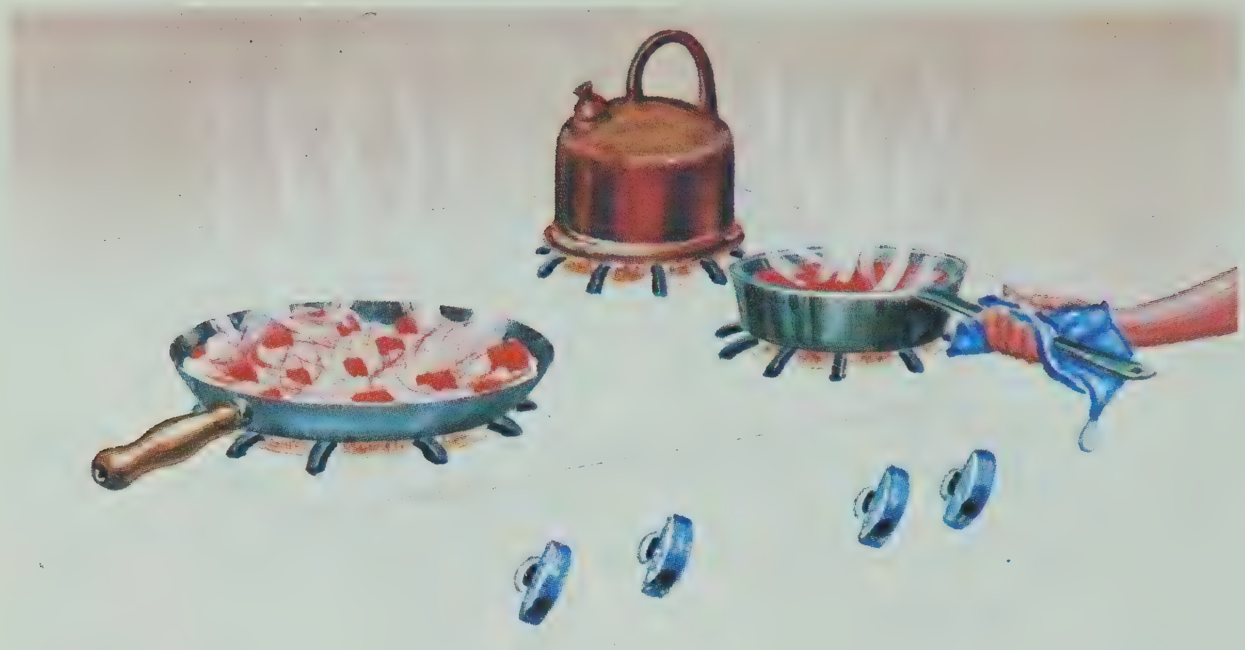


Fig. 50–1

Heat travels by conduction.

YOU NOW KNOW

- Warm air is less dense and lighter than an equal volume of cold air.
- Heat is transferred by conduction, convection and radiation.

3. HEAT AND THERMOMETERS

A THERMOMETER (thur-MOM-uh-tur) is an instrument that measures *temperature* (the degree of heat). All thermometers work on the idea that materials *expand* (get bigger) when they get hot and *contract* (get smaller) when they cool.

Some thermometers use liquids such as mercury, kerosene or alcohol in a closed glass tube. The liquid expands and contracts as temperatures change. Other thermometers use a bar made of two metals instead of a liquid.

Heat Travels By

1. CONDUCTION:	heat goes from molecule to molecule in solids.
2. CONVECTION:	warm air or water currents
3. RADIATION:	transfer of heat by energy waves

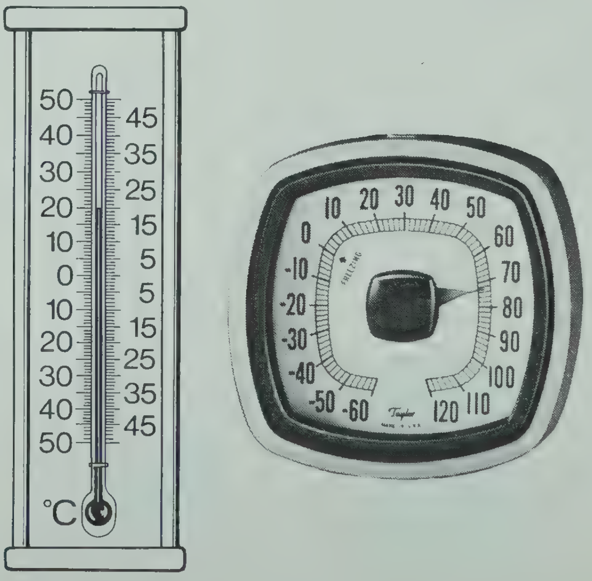


Fig. 50–2

Two kinds of thermometers. Which would you use in an oven?

FREEZING POINTS AND BOILING POINTS COMPARED

FREEZING			BOILING	
Fahrenheit	Celsius		Fahrenheit	Celsius
32°F	0°C	Water	212°F	100°C
—202°F	—130°C	Alcohol	173°F	78°C
—40°F	—40°C	Mercury	675°F	357°C

Such thermometers do not crack, so they can be used in ovens and very cold refrigerators. All thermometers show temperature in degrees.

4. THE NOONDAY SUN AND THE SETTING SUN

An old expression from India says, "Only mad dogs and Englishmen go out in the noonday sun." At noon, the sun's rays make the greatest angle with the earth. They are almost directly overhead. It is therefore the hottest time of the day. Native Indians and probably Englishmen knew it was wiser to stay indoors at noon. As the earth rotates away from the sun, the earth gets only slanted rays. So the air is not heated as much. As the sun sets, the air gets cooler and cooler. Scientists know there is really no difference between the sun at noon and the setting sun. It is just that the air is not heated as much at one time as at another.

5. WHY DOES THE AIR COOL OFF?

If the earth and its waters continue to radiate heat back into space, what happens to the heat already in the atmosphere? Let's go back to the Bunsen burner in Fig. 49-2A. If you hold your hand 60 cm above the flame, your hand feels cooler than it did when it was 30 cm above. If you hold a pinwheel far above the flame, it will not spin. Why?

As the air expands more and more, it cools more because the heat is now spread out. So you see that two conditions together cause our atmosphere to heat up and to cool down. First, radiation heats the air; second, the expansion of air cools it.

On a hot day when it is humid and dusty, the evening air remains quite warm. Air which contains a lot of moisture and a lot of dust cannot expand as well as dry air. It acts like a huge envelope that traps the warm air above the earth. When there are clear skies, the air cools faster.

6. IT'S COLD UP THERE!

Believe it or not, the picture on page 52 was taken during the summer. The snow never melts on top of this mountain. Why does it remain so cold in higher altitudes?

We saw that we get our heat by radiation from the surface of the earth. As we go higher up, the warm air expands and spreads out. And we learned that this made the air get

TEMPERATURE CHANGES WITH ALTITUDE

Height in m	Temp °C	Drop °C
Zero (sea level)	23.9	
300	21.9	2
600	20.0	3.9
1200	16.1	7.8
3050	4.4	19.5
3750	0 (freezing)	23.9
6100	−15.2	39.1
8850 (Mt. Everest)	−71.6	95.5

cooler. How much cooler? The table above shows that for each 300 m of height (altitude), there is a drop in temperature of 2°C.

Fig. 52–1

These skiers are enjoying the snow even though it's summer.

7. TEMPERATURES IN THE UPPER ATMOSPHERE

We have been talking mostly of temperature in the air right above us. What is it like in the upper layers of the atmosphere? In the different layers of the atmosphere, the temperature keeps falling at the rate of 2°C for each 300 m we go higher, until we reach the imaginary line at the top of the troposphere. The temperature at this place is −55°C. It stays at −55°C until a height of 29 km is reached at the imaginary top of the stratosphere. The temperature then rises as the altitude rises. It climbs to 77°C at about 50 km above sea level. The temperature then drops again. At 80 km up it reaches −33°C. From then on the higher one goes, the higher the temperature climbs. At 160 km above sea level the temperature is about 260°C. At 400 km above sea level, the temperature is about 1100°C. You can see one of the big problems in space travel. We must find ways to overcome extreme cold and extreme heat.

8. WHEN TEMPERATURES ARE "UPSIDE DOWN"

As you have learned, warm air is lighter than cold air. Warm air near the earth's surface rises. Cool air moves in to take the place of the rising air. The rising warm air cools off. This is the usual story.

Sometimes, a warm layer of air near the surface of the earth cools off quickly. The layers of air higher up are now warmer than the air below. The colder, heavier air cannot rise. The temperature layers are upside-down. This is called a temperature INVERSION (in-VUR-zhun). The inversion layer acts like a blanket that keeps the warm air trapped below.

In the usual condition, the warm air rises and carries particles and gases upward. The cool, clean air moves in. During inversion, the particles and gases are trapped near the earth. The result is a special kind of fog called SMOG. We shall learn more about this in a later chapter.

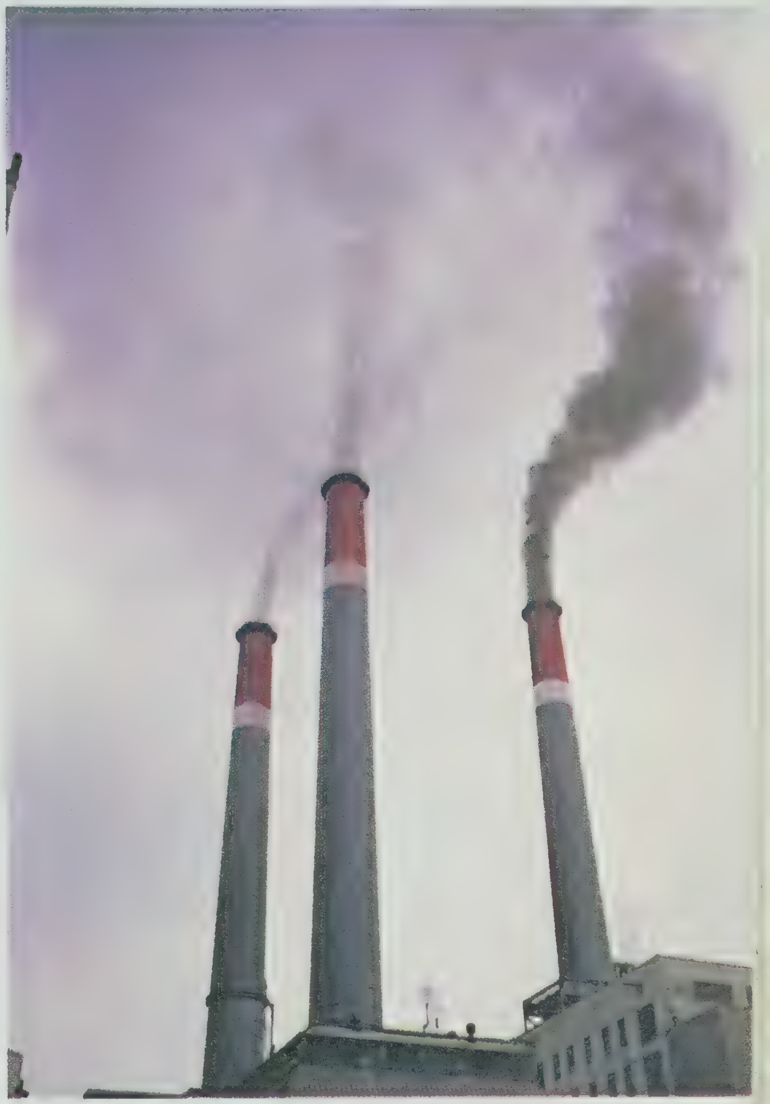


Fig. 53–1

How will a temperature inversion affect the movement of the particles being dumped into the atmosphere by this plant?

YOU NOW KNOW

- The atmosphere cools by radiation and expansion.
- The temperature of the atmosphere drops at a steady rate until the top of the troposphere.
- Scientists have studied the different temperatures in the different layers of the atmosphere.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 7?

1. Warm air is less dense and weighs less than cold air.
2. Heat travels by conduction, convection and radiation.
3. Heat radiates from the air to affect thermometers.
4. It's cold on high mountains.

II. In which paragraph do you find the answer?

1. How does the atmosphere lose its heat?
2. How is the drop in temperature related to altitude?
3. What is the idea behind a thermometer?
4. How does the body of a frying pan get hot?

III. Knowing What and Why

1. Ventilating a room is done by
    - a. moving the radiators.
    - b. cooling off the room.
    - c. starting convection currents.
    - d. increasing the humidity.
2. In every thermometer, some material responds to heat by
    - a. expanding or contracting.
    - b. expanding and conduction.
    - c. radiation and conduction.
    - d. conduction and reflection.
3. The noonday sun is
    - a. cooler because rays are direct.
    - b. hotter because rays are direct.
    - c. radiating less energy.
    - d. reabsorbing heat rays.
4. Moisture and dust in the atmosphere will tend to
    - a. trap heat near the earth.
    - b. distill the vapor in the atmosphere.
    - c. cause convection currents.
    - d. reduce air pressure.

IV. True or false? Explain your answer.

1. In Fig. 52–1, the photo deals with altitude and temperature.
2. In the table in Paragraph 6, at 1200 m, the temperature is 7.8°C.
3. In Fig. 49–2A, the height of the pinwheel above the flame will make no difference.
4. In Fig. 50–2, you can use both the thermometers in the oven while you bake a cake.

V. Can you draw a graph?

Study the table in Paragraph 6. Get a piece of graph paper and rule it to show the figures. First, do it roughly in pencil. Let your science teacher check it before you do it in final form.

VI. For the Science Reporter

Use an almanac or an encyclopedia. Look up the 10 tallest mountains in the world. List the temperature on top of each for the first day of summer.

VII. Brain Teasers

1. Which is hotter, water at 212°F or at 100°C? Explain your answer.
2. If the temperature at sea level is 20°C, what will be the approximate temperature in that same area on a mountain 1200 m tall? *Hint:* 1200 m = 4 x 300 m.

8

TARGET
How do winds start?

The Blowing Winds

1. A BAG OF WINDS

If you had lived in Greece two thousand years ago, you would have had no trouble answering the Target Question. You would have believed in the god, AEOLUS (EE-o-lus). Aeolus, they said, had a huge bag in which he kept all the winds of the earth. When he felt like it, he could simply open the bag and let one of the winds escape. No wonder the ancient sailors prayed to Aeolus! However, our scientific answer is more correct and easy to understand.

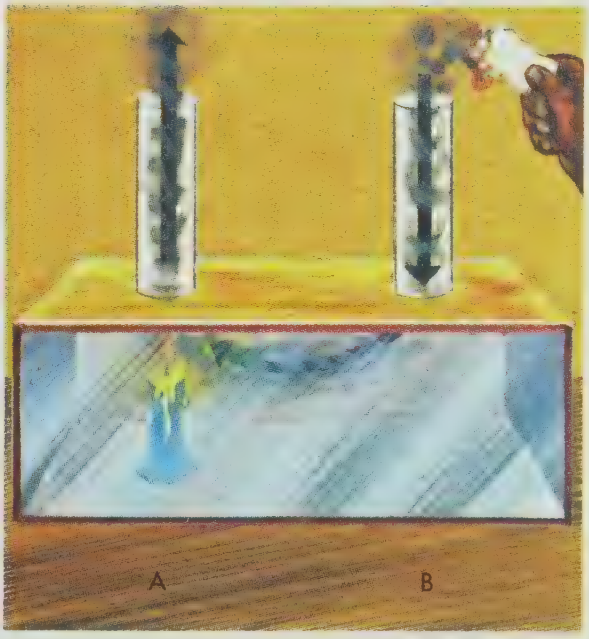


Fig. 55–1

How does the convection box explain how air currents begin?

2. STARTING A WIND

DO AND DISCOVER

Investigation 9: How do air currents get started?

The box shown in Fig. 55-1 is made of metal and has a sliding front door of glass. The two openings are fitted with glass chimneys. Light a candle at A. Wait a few moments. Hold a piece of lighted smoke paper at the top of B. You can see the path of the smoke as shown by the arrows. (What happens if you transfer the candle to B and repeat with the smoke paper?)

Remember that the candle warms the air above it. The air becomes less dense, and expands. Of course, it moves up Chimney A and out. What is left now? For a brief second, there is less pressure at the left. The cooler air reaches over from B to A. Now there is a partial vacuum at B. Heavier, cooler air reaches down Chimney B. You have set up a *convection current*. (When you reverse the candle, you reverse the current.) What causes this? It is caused by *unequal* heating of the air inside the box. Warm air expands. Cool air moves in and pushes up on the warm air. The current in A is upward; the current in B is downward.

3. CURRENTS AND WINDS

In the experiment in Paragraph 2, we saw that air is made to move by unequal heating. The warm air is at a lower air pressure. The air moves from the higher pressure to the lower pressure. The warm air expands, cools and then sinks.

Remember that the equator of the earth receives most of the direct rays of the sun. It therefore becomes hotter than other parts of the earth. As in this experiment, the earth gets unequal heating. The heated air expands over the equator. The area around the equator develops low pressure. Air moves in from the sides. A *wind* has started.

AIR MOVEMENTS
MAY BE

SIDE TO SIDE
(HORIZONTAL) WINDS

UP AND DOWN
(VERTICAL) CURRENTS

4. A KITE AT THE BEACH

When you fly a kite at the beach, does it fly toward the sea or toward the land? That depends on the time of day. Let's see why.

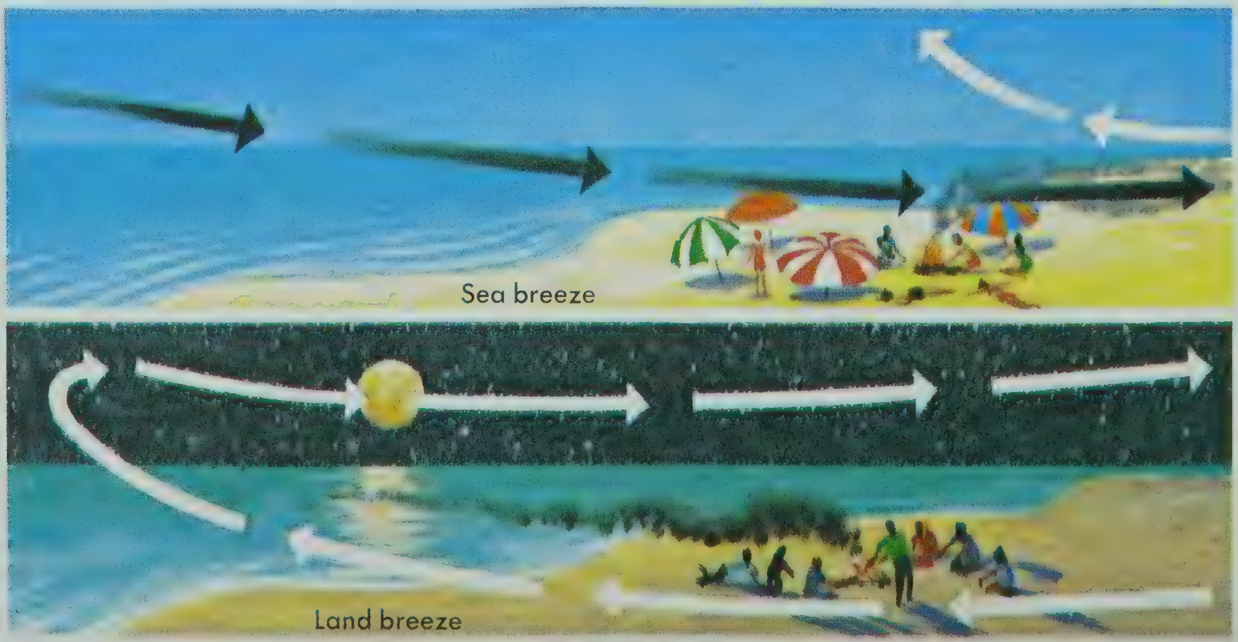


Fig. 56–1

Can you explain why the smoke of the picnic fire is blowing in two different directions?

Let your kite out at about 11:00 a.m. The sun has risen and has been shining for some time. But the beach absorbs heat faster than the water. Air expands over the beach. Cool air from the sea moves into the lower pressure to form a *sea breeze*. Your kite blows toward the beach.

Now draw your kite in and come back at 7:00 p.m. The sun has set. The sea had warmed up later. It now begins to give off its warm air. This warm air expands. Now the air pressure is lower over the sea. Cool air from over the beach rushes out toward the sea to form a *land breeze*. Your kite blows toward the sea. Winds always take the name of the direction *from* which they blow.

YOU NOW KNOW

- Currents and winds are caused by unequal heating of the earth.
- Unequal heating is found at beaches, at mountains and at the equator.
- Currents and winds move from higher pressure areas to lower pressure areas.

5. DO YOU REMEMBER YOUR GEOGRAPHY?

The diagram shows our earth (a planet). We have drawn several imaginary lines. The EQUATOR (ee-KWAY-tor) is around the middle. The *Tropic of Cancer* is 23.5° north of the equator. The *Tropic of Capricorn* is 23.5° south of the equator. The *Arctic Circle*, near the North Pole, is 66.5° north of the equator. The *Antarctic Circle*, near the South Pole, is 66.5° south of the equator. These are the *lines* of *latitude*.

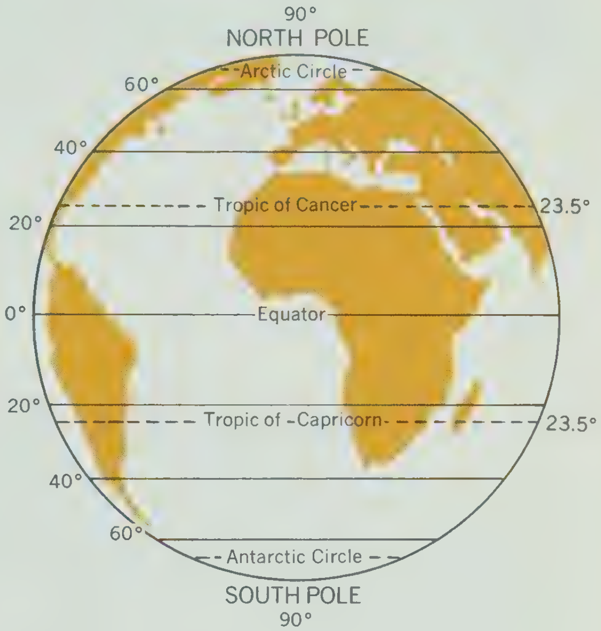


Fig. 57–1

Lines of latitude are drawn around the earth parallel to one another. Why are there two sets of the same numbers?

6. BELTS OF CALM AND BELTS OF PRESSURE

Land breezes and sea breezes are small winds. They cover a small area. Scientists know that our planet has very large winds which cover wide areas. Such winds are called *planetary winds* because they blow across our planet. The area in which they blow are called *wind belts*. Let us see how they get started. Let us see where they go. As you read, follow the map in Fig. 58-1.

As the warm air expands over the equator, it flows north and south toward the poles. The area over the equator moves very little. We say it is a belt of *calm*. It is called the DOL-

HORSE LATITUDES		DOLDRUMS
Falling, calm	Air movement	Rising, calm
Cool	Air temperature	Warm
High	Air pressure	Low

DRUMS (DOL-drumz). This warm air moves high above the earth and becomes cool. It begins to sink down at about the Tropic of Cancer and the Tropic of Capricorn. Find these on the map. These two tropics are also belts of calm. These are called the *horse latitudes*. Since the air is sinking, these belts are areas of high pressure.

7. THE BIG WINDS BLOW

What happens now? Just what you would expect! The air from the higher pressure horse latitudes blows towards the low pressure of the doldrums. Huge, strong winds are the result. These are the famous *trade winds*. Notice that there are two belts of trade winds: north of the equator and south of the equator.

The high pressure at the horse latitudes also starts winds blowing toward each pole. Just below each pole, there is a low pressure area. These winds are the *westerly winds*. Notice that there are westerly winds in the northern hemisphere and in the southern hemisphere.

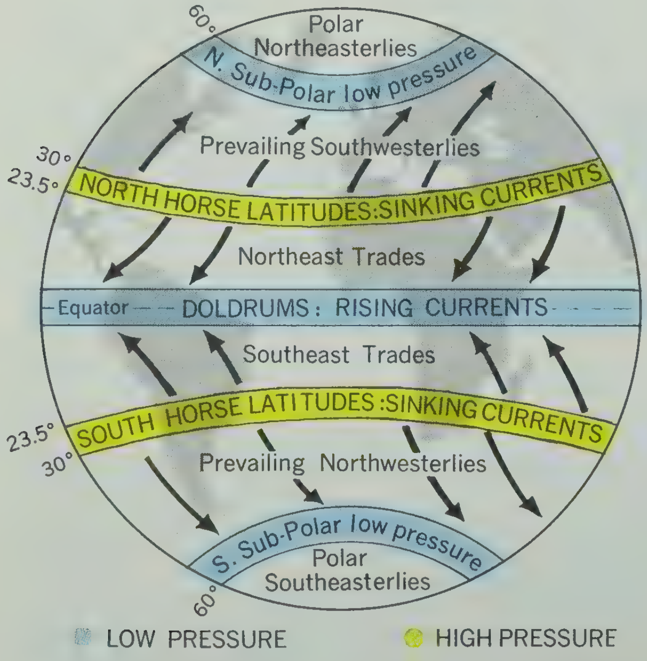

60°
Polar
Northeasterlies
N. Sub-Polar low pressure
Prevailing Southwesterlies
30°
23.5°
NORTH HORSE LATITUDES:SINKING CURRENTS
Northeast Trades
Equator
DOLDRUMS: RISING CURRENTS
Southeast Trades
23.5°
30°
SOUTH HORSE LATITUDES :SINKING CURRENTS
Prevailing Northwesterlies
S. Sub-Polar low pressure
Polar
Southeasterlies
60°
LOW PRESSURE
HIGH PRESSURE

Fig. 58–1

How did we get the colorful names *horse latitudes* and *trade winds*? Look them up in your encyclopedia.

8. THE WINDS ARE "TWISTED"

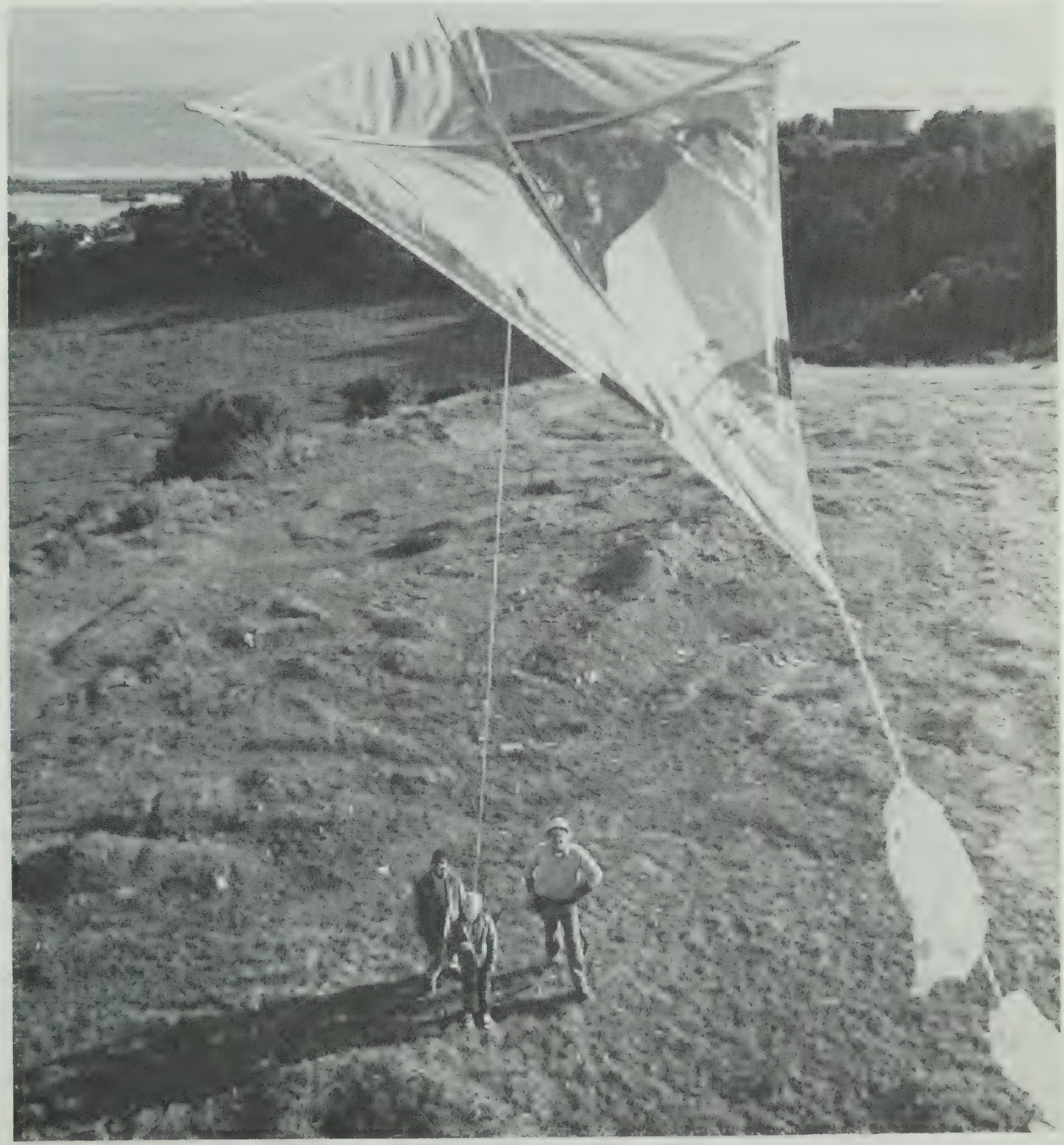
Why are the arrows for the westerly winds and trade winds shown curved? Why not straight? The reason is that the earth rotates. And the motion of the earth "twists" the winds. Now you can see that in the northern hemisphere the trade winds are *south*westerly (from the southwest) to the northeast. In the southern hemisphere, they are *north*westerly (from the northwest) to the southeast. The trade winds are also twisted to the right of their paths in the northern hemisphere; to the left of their paths in the southern hemisphere.

YOU NOW KNOW

Major Planetary Winds			
	Types	**From**	**Towards**
Westerly	Southwesterly Northwesterly	North Horse Latitudes South Horse Latitudes	North Pole South Pole
Trade	Northeast Trades Southeast Trades	North Horse Latitudes South Horse Latitudes	Doldrums Doldrums

Fig. 59–1

When will the kite fly toward the land?



UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 8?

1. Unequal heating of land starts winds and air currents.
2. Parts of the earth have no winds at all.
3. Land breezes blow from land to sea.
4. Winds are directed by the earth's rotation and convection.

II. Explanation, please . . . answer in one or two sentences.

1. How are sea breezes started?
2. How are wind belts started?
3. Where are the belts of calm?
4. Why do winds north and south of the equator curve?

III. Knowing What and Why

1. Convection currents result from
   a. unequal heating of air.
   b. a drop in barometric pressure.
   c. rotation of the earth.
   d. too much radiation at the equator.
2. Horse latitudes are
   a. trade winds.
   b. belts of calm in the tropics.
   c. belts of calm near the poles.
   d. strong currents on both sides of the equator.
3. Southwesterly winds blow
   a. from southeast to southwest.
   b. from the south to the west.
   c. toward south and west.
   d. from south and west.

IV. True or false? If the statement is true, write *true*. If the statement is false, change the *underlined* words to make the statement true.

1. Planetary winds are caused by the earth's rotation.
2. In the area around Boston, the trade winds are southwesterly.
3. At 1:00 p.m. on a sunny day at the beach, the wind is a land breeze.
4. Movement of warm air is conduction.
5. When we say a person is "in the doldrums" to describe how he feels, we mean he is inactive.

V. For the Artists and Builders

1. Copy Fig. 58–1 on to a large poster board.
2. Construct the convection box in Fig. 55–1. Lamp chimneys can be bought in a hardware store. However, it will work fairly well even without the glass chimneys.

VI. Understanding the Diagrams

1. In Fig. 55–1, suppose you had a lighted candle under both chimneys. What would happen? Why?
2. In Fig. 56–1, what would happen on a cloudy day when the sun is not shining?

VII. Complete the table by choosing the right words.

Do not write in this book.

	Horse Latitudes	Doldrums
Air pressure: high or low?		
Temperature: high or low?		
Currents: rising or falling?		
Winds: calm or forceful?		

9

TARGET
How does water enter and leave the atmosphere?

The Water in Our Atmosphere

1. WHERE DOES THE MOISTURE IN THE AIR COME FROM?

The earth has huge quantities of water. Three-quarters of the earth is hydrosphere: oceans, lakes, bays, seas and rivers. The warmth of the sun EVAPORATES (ee-VAP-or-ates) this water into the atmosphere. In the process of respiration, plants and animals give off water. Fires, which burn hydrocarbons, give off water. Where does the evaporated water go? Most evaporated water (water vapor) stays in the troposphere, probably not higher than 10 km. Since winds and currents move air, water vapor in the air moves along with it and is scattered to other parts of the atmosphere. (See Fig. 66-1.)

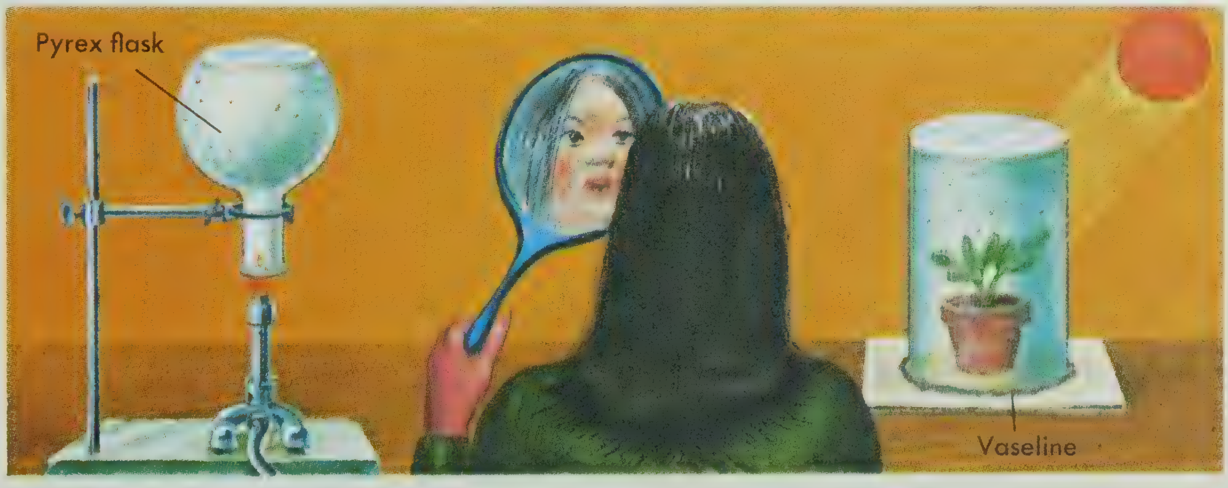


Fig. 61–1

The air keeps getting water vapor. Can you tell why you see drops of liquid water in each case?

2. IT'S MUGGY TODAY!

On muggy days your clothes seem to stick to you. You seem to perspire much more than usual. Your mother complains that the clothes on the line won't dry. What you are really talking about is the HUMIDITY (hyou-MID-i-tee). Humidity is the moisture in the air.

Why does humidity change? Why is the air more humid on some days than on others? The answer depends on two things: the temperature of the air and the movement of the air. Warm air holds more water than cold air. Air which moves can cause more evaporation than still air.

Air with much water vapor → HIGH HUMIDITY
Air with little water vapor → LOW HUMIDITY

3. HOW HIGH IS THE HUMIDITY?

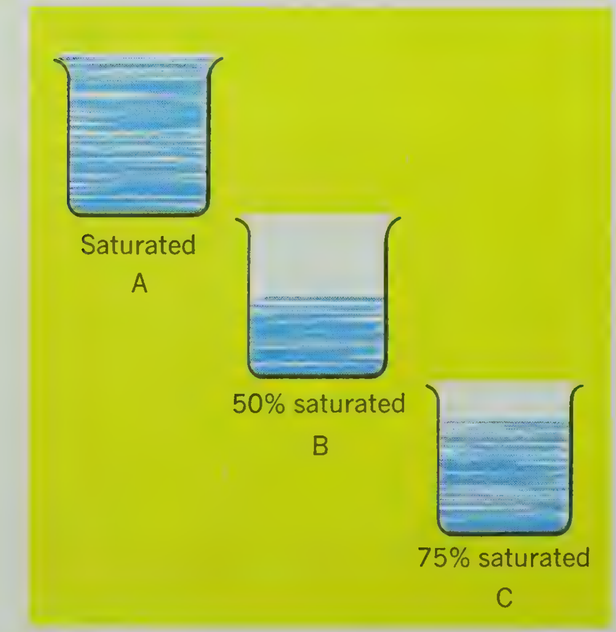


Fig. 62–1

Use these diagrams to explain relative humidity.

How much moisture can the air hold? If we pour water slowly over a sponge, it absorbs the water. But there comes a time when it can hold no more water. The sponge is SATURATED (SATCH-you-ray-ted). It is the same with the air. When air can hold no more water, it is saturated. In Fig. 62-1, Jar A is filled with sawdust. It is saturated. Jar B is only half-saturated. Its saturation is 50%. Jar C is ¾ or 75% saturated.

Now let's think of each grain of sawdust as a molecule of water vapor in the air, as humidity. If the air holds only 50% of the amount of water it might hold, then it can accept 50% more. We now speak of *relative humidity*. This is a percentage (%) that tells how much moisture the air holds, compared with the most that it can hold.

YOU NOW KNOW

- ► Water enters the atmosphere by evaporation from the oceans, bays and rivers; from plants and animals and from burning of hydrocarbons.
- ► The amount of water vapor in the air is called humidity.
- ► Relative humidity is the amount of water the air holds compared with how much water it can hold.

4. SOME MOISTURE COMES OUT

Walk on the grass any cool morning. Your shoes may get wet. Or look at the roofs of the cars parked on your street. It has not rained, but the cars are wet. A cold bottle of soda pop on the table begins to "sweat." The water vapor in the air is being cooled by the cold surface of the bottle. You are observing condensation. It is the drop in temperature that causes this change.

During the night, the temperature of the air dropped and caused condensation. The drops of water are called *dew*. The temperature at which this condensation takes place is called the *dew point*. If this same condensation takes place on a very cold night, when the temperature is below 0°C, the drops freeze to form *frost*.

Above freezing → Dew

CONDENSED WATER VAPOR

Below freezing → Frost

5. OVERCAST SKIES

Have you heard a weather report tell you that there will be overcast skies? Condensation takes place high in the atmosphere. Water vapor in the air condenses around particles of dust. The condensed droplets of water form a *cloud*. Clouds are held up in the air by convection currents. When you look up, you see the cloud "floating" high above the earth's surface. When a cloud hangs low, near the surface of the earth, it is called a *fog*. Clouds have been studied carefully. The pictures on page 64 will tell you a little about them. Would you like to make a cloud? Follow the simple demonstration.

DO AND DISCOVER

Investigation 10: How are clouds formed?

What you do:

1. Use the setup shown in Fig. 63–1.
2. Blow hard into the tube or use a bicycle pump. Release suddenly.

What you see:

A cloud will form in the bottle.

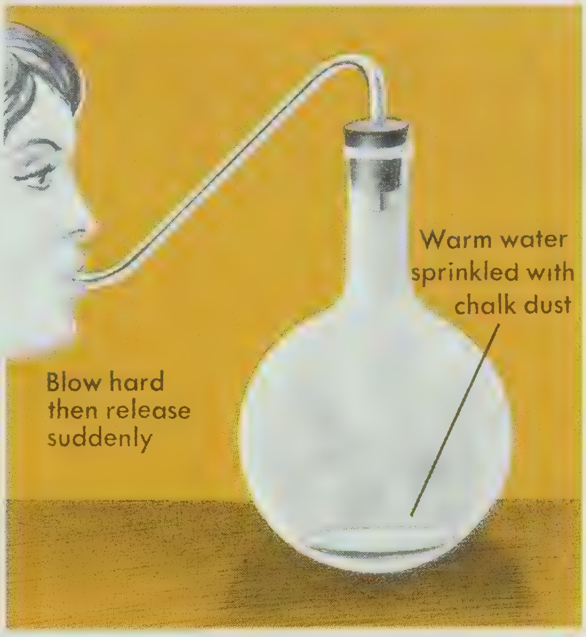

Warm water sprinkled with chalk dust
Blow hard then release suddenly

Fig. 63–1

Why do you stop blowing suddenly?

What you learn:

There are three conditions needed for water vapor to condense into a cloud:

warm moisture

dust particles on which the water vapor condenses

a drop in pressure at the same time that the moisture is cooled

6. KINDS OF CLOUDS

Of course, there are different kinds of clouds. See the pictures below and read what it says about them. Notice that different clouds are found at different heights.

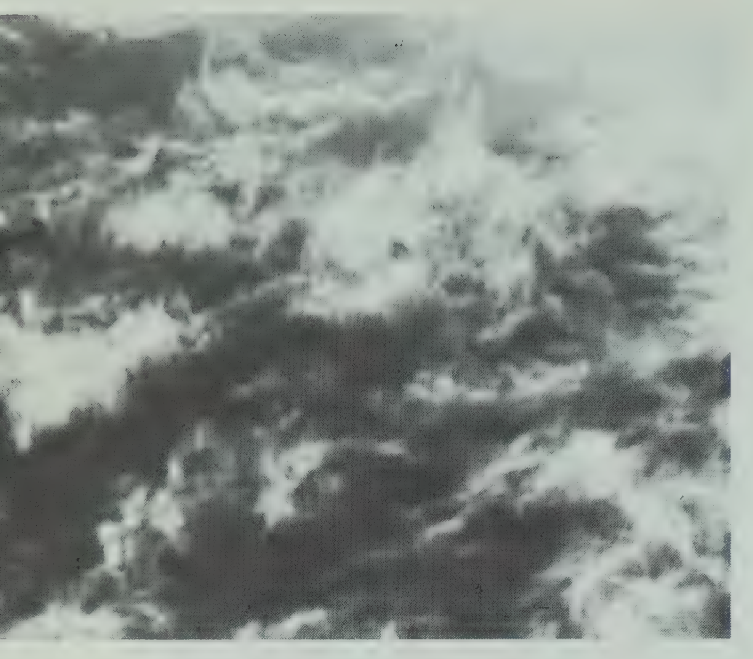


Fig. 64–1

ICE CLOUDS (CIRRUS). On clear days, about 8 km up; contain ice crystals; rain or snow in a day or two.

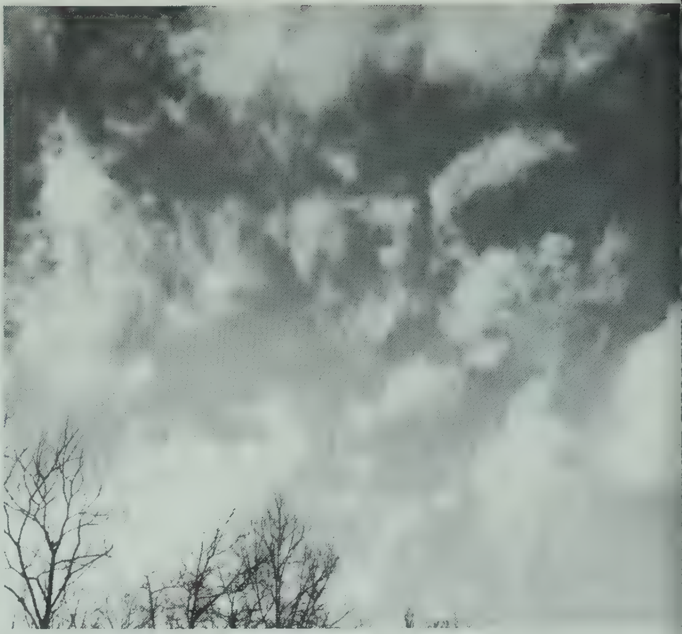


Fig. 64–2

FLUFFY CLOUDS (CUMULUS). On clear days, about 5 km up; fair-weather clouds.

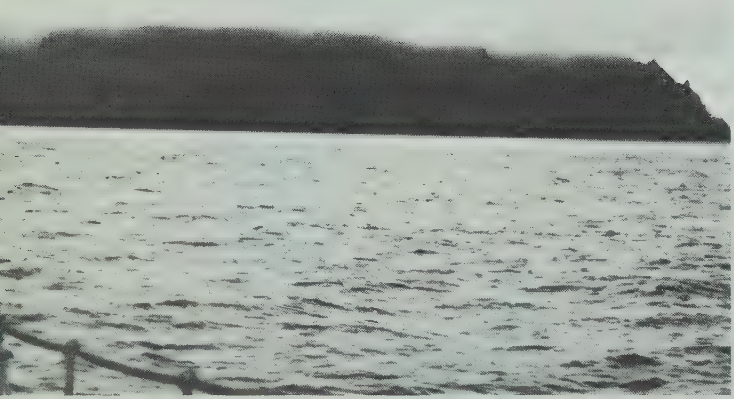


Fig. 64–3

LAYERED-FLAT CLOUDS (STRATUS). Fluffy clouds gathered together to form grey skies; rain in two or three hours.

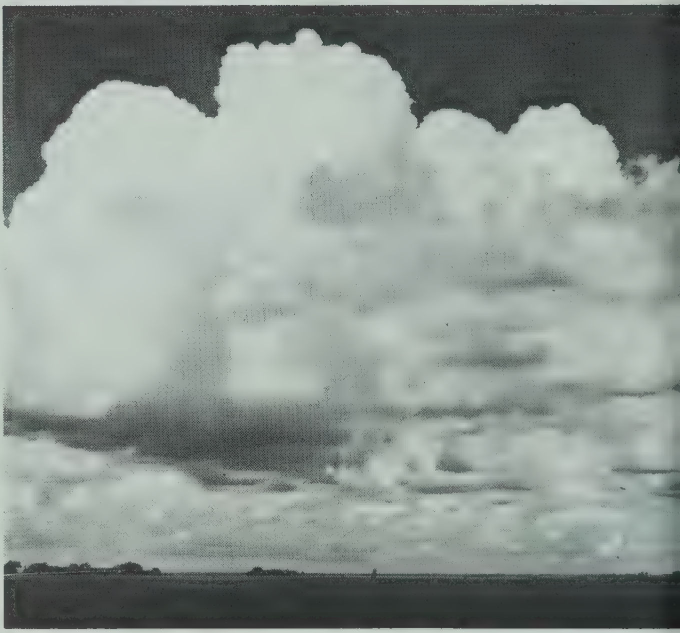


Fig. 64–4

THUNDERHEAD CLOUDS (CUMULONIMBUS). Big, heavy, black clouds; formed from fluffy clouds; heavy rain with thunder and lightning.

7. WHEN THE DROPS GET TOO BIG

When the condensed drops of water vapor in the air become too big and too heavy to be held up by the convection currents, they fall out of the atmosphere. Scientists call this PRECIPITATION (pree-SIP-i-TAY-

FORMS OF PRECIPITATION

Rain	Drops of water form.	Above 0°C
Snow	Water vapor freezes directly into crystals.	Below 0°C
Sleet	Raindrops freeze to bits of ice.	Below 0°C
Hailstones	Blowing raindrops freeze over and over in layers.	Below 0°C

shun). You will recognize this as *rain, snow, hail* or *sleet.*

YOU NOW KNOW

- Water vapor condenses from the atmosphere at the dew point.
- Water vapor may form dew or frost.
- Clouds are formed by condensed water vapor above the earth.
- Clouds may precipitate their water as rain, snow, hail or sleet.

DO AND DISCOVER

Investigation 11A: How can we show precipitation?

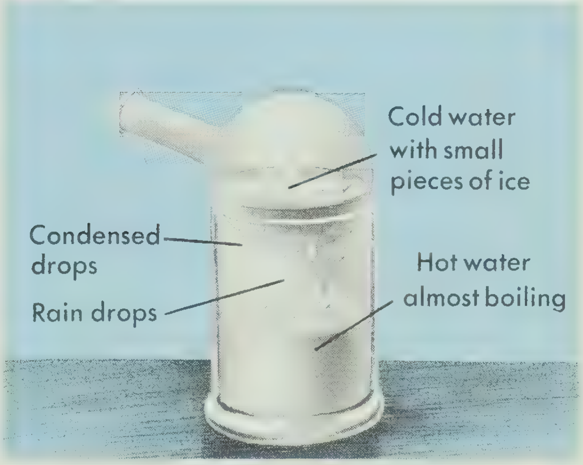


Fig. 65–1
Answer question VIII, page 67.

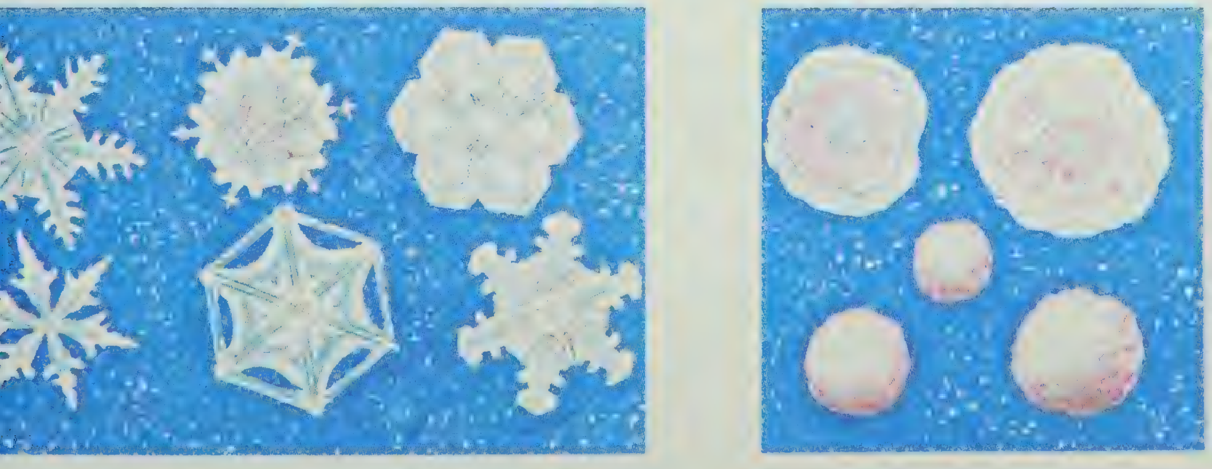


Fig. 65–2
A. All snowflakes have six points.

B. Hailstones form from rain by several freezings to form layers.

THE WATER CYCLE

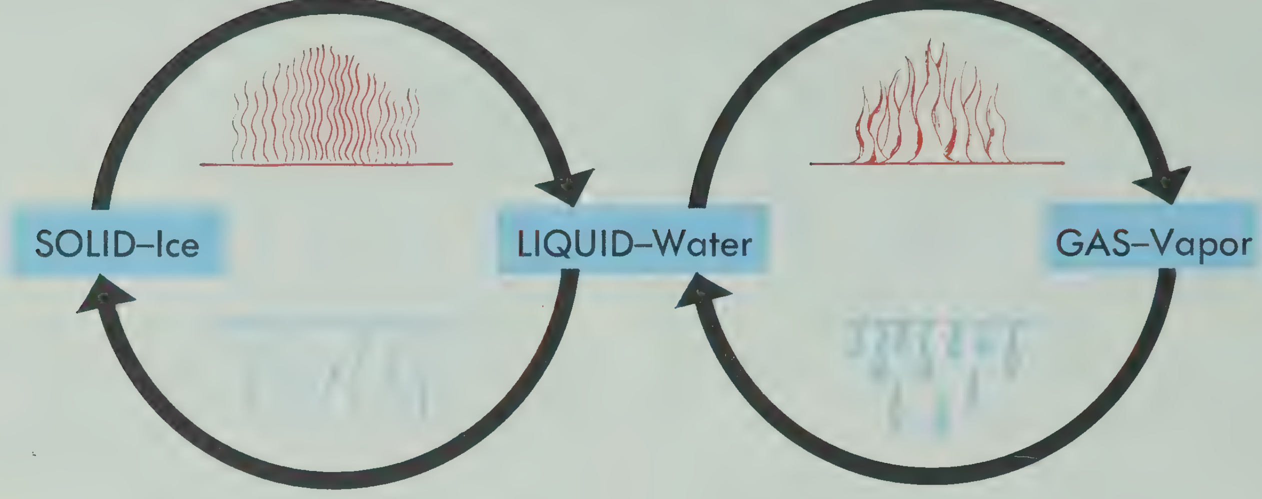


Fig. 66–1

Water is found in three forms: as water (liquid), as vapor (gas), and as ice (solid). Which of these forms precipitation?

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 9?

1. The amount of water vapor in the air keeps changing.
2. Living things add water to the air.
3. All clouds are really alike.
4. Water vapor from the air condenses and precipitates.

II. In which paragraph do you find the answer?

1. Where does evaporated water go?
2. When is the air saturated with water?
3. How is a fog different from a cloud?
4. How is snow formed?

III. Knowing What and Why

1. Hailstones are
   - a. frozen snow crystals.
   - b. frozen raindrops.
   - c. snowflakes without crystals.
   - d. spheres of sleet.
2. Clouds will form if there is
   - a. warm moisture, high pressure and dust.
   - b. warm moisture, low pressure and dust.
   - c. oxidation, respiration and distillation.
   - d. high pressure and low humidity.
3. Humidity drops when
   - a. warm air is cooled and moves.
   - b. the air is cooled and stands still.
   - c. air pressure rises.
   - d. evaporation decreases.
4. Drops of dew appear on the ground in the morning because
   - a. frost changes to dew.
   - b. cool air evaporates water from the grass.
   - c. the air grew cooler and caused condensation.
   - d. there are no winds to evaporate the water.

IV. Finish the story by choosing the correct word from the list below.

Overcast skies refers to (1). When water condenses out of the atmosphere near the ground, it may form (2) or (3), depending on the temperature. Forming of clouds depends on the presence of particles of (4) in the atmosphere. When the condensed drops of water become too big and too heavy, (5) takes place. In order for snow to form, the water must freeze to form (6) without first condensing to (7). The heaviest storm clouds are called (8) and are filled with water.

dew
dust
crystals
cirrus
clouds
water
fog
precipitation
cumulonimbus
frost

V. Give the Opposites

1. Evaporation ____________
2. Saturated ____________
3. Dew ____________
4. Land breeze ____________
5. Northwesterly ____________

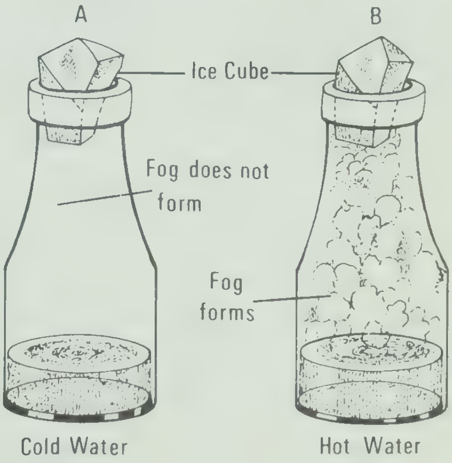
VI. Explanation, Please

1. People sometimes breathe out on their eyeglasses before polishing them.
2. When it is raining, the relative humidity is at or very close to 100%.
3. Home owners often wrap insulation around the cold water pipes in their basements.

DO AND DISCOVER

VII. Investigation 11B: How can we show a fog forming?

Would you like to form a fog in a bottle? Fill a milk bottle with hot water. Pour out the water, leaving about 3 cm in the bottom. Place an ice cube on the mouth of the bottle as shown in the diagram. Set up a control, using cold water instead of hot. Why does fog form in one bottle, but not in the other?



VIII. Understanding the Investigation

Examine Fig. 65–1.

1. Why must the water in the flask be cold?
2. What process is taking place?
3. What is another name for the rain?
4. Has the dew point been reached? Explain.

10

TARGET
How can we control the dangers of air pollution?

Our Foul Air

1. DEATH FROM THE AIR

The town of Donora, Pennsylvania, was a quiet, peaceful American town. Then, in 1948, it burst into the news. A tragedy had taken place. A thick, dense, smoky "blanket of air" settled over the town. When it was all over, there were seventeen dead and 5 000 sick! This is a story that has taken place too many times. In 1962, the city of London, in a similar tragedy, counted 400 dead! A new word was born: *smog* which means "smoke in fog."

2. BLANKETS OF AIR . . . TENTS OF DEATH

Reread paragraph 8 on page 53. Now let us look into Donora, Pennsylvania. Donora is in a low valley, and in 1948, it had three large factories: steel, sulfuric acid and chemicals. On that day, the temperature inversion did not allow the air to carry the soot and smoke up and away. Instead, they were trapped over the town.

A look at the map will show you that Los Angeles is also in a valley, with three mountain ranges around the city. An inversion layer forms a perfect blanket to trap the wastes from the auto's tail pipes.

3. SOMETHING EXTRA

Look back at Fig. 11-2. Of course, most of the materials shown remain in the same amounts shown. The CO_2 and the water vapor keep changing slightly. This is what we call "pure

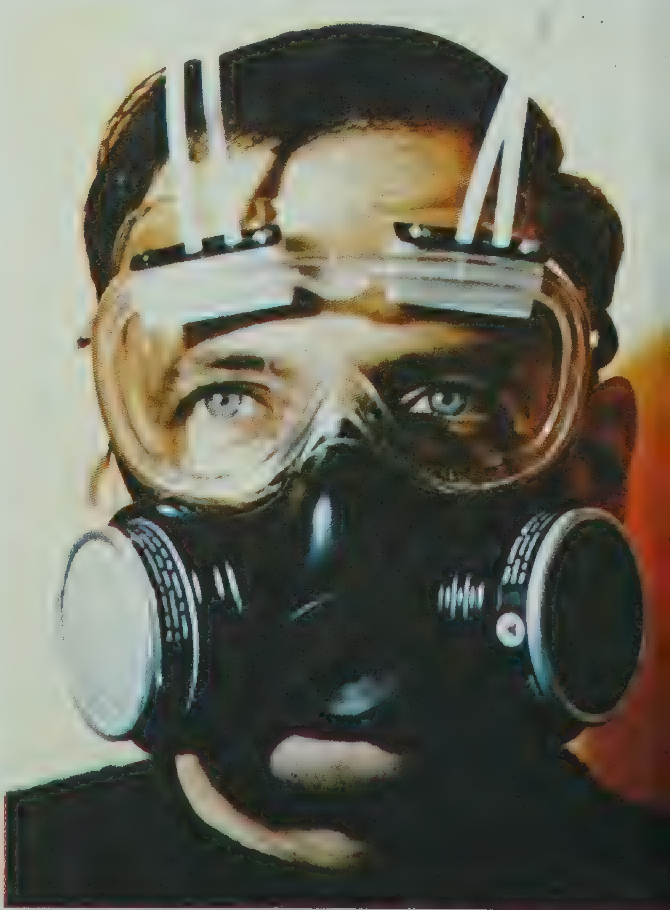


Fig 68–1

This man is taking an eye irritation test to see how automobile exhaust gases affect us.

air." Of course, you know that air is never really pure. It always has dust and other materials. As a matter of fact, the air and the skies appear blue because the dust particles scatter the white sunlight. But man and his industries have begun adding foreign materials to the air. Any foreign material in the air is called a POLLUTANT (po-LOO-tant). We call this condition AIR POLLUTION (po-LOO-shun).

AIR + POLLUTANTS ⟶ POLLUTED AIR

4. THE VILLAINS OF AIR POLLUTION

Where do pollutants come from? Look at Fig. 69-1. As you see, many of these come from some form of burning. There are other ways. Grinding of metal, stone and plastics may leave very fine dust which escapes into the air. This dust is a pollutant.

5. UNBURNT CARBON

The most dangerous pollutants are chemicals. Fires often do not burn their fuel completely. This leaves unburnt carbon as the fine dust we call SOOT (rhyme with foot). When carbon burns, it usually forms carbon dioxide. But if it burns with little air, it forms the dangerous, odorless, poison gas, carbon monoxide.

$C + O_2 \rightarrow CO_2$ carbon dioxide
$2C + O_2 \rightarrow 2CO$ carbon monoxide

If you hold a shiny piece of metal near the tailpipe of a car whose engine is running, a black deposit will soon form on the metal. This is unburnt carbon. DANGER: *Do not breathe the exhaust gas. It contains carbon monoxide.*

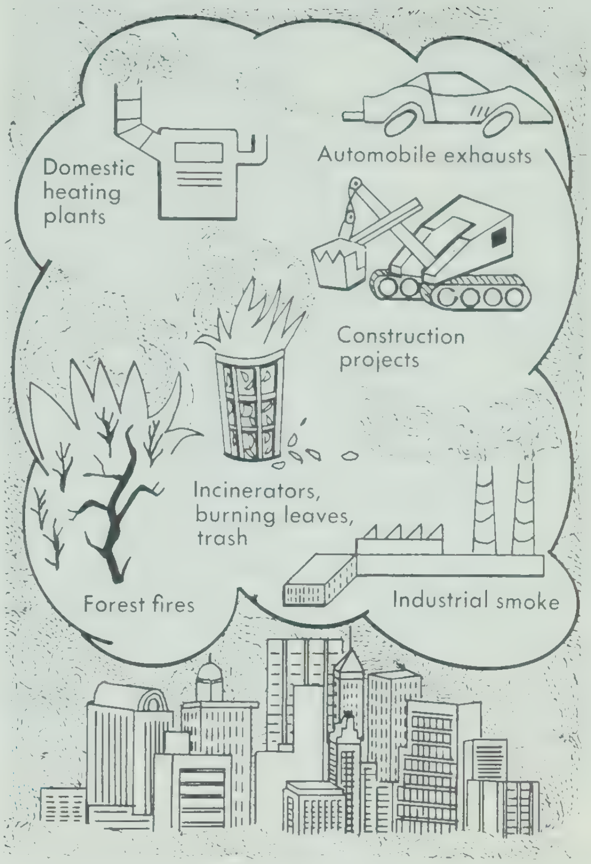


Fig. 69–1

These are some of the causes of air pollution.

DO AND DISCOVER

Investigation 12: What happens to unburnt carbon in a flame?

1. Light a Bunsen burner. Turn the collar until you get a yellow flame. Now hold a brightly polished aluminum coffeepot low over the flame. A black ring will be left on the aluminum.
2. If you have a gas cooking stove at home, there is a collar on the front, near the pipe which brings the gas into the burner. You can adjust this collar to make the gas burn blue or yellow. Why?

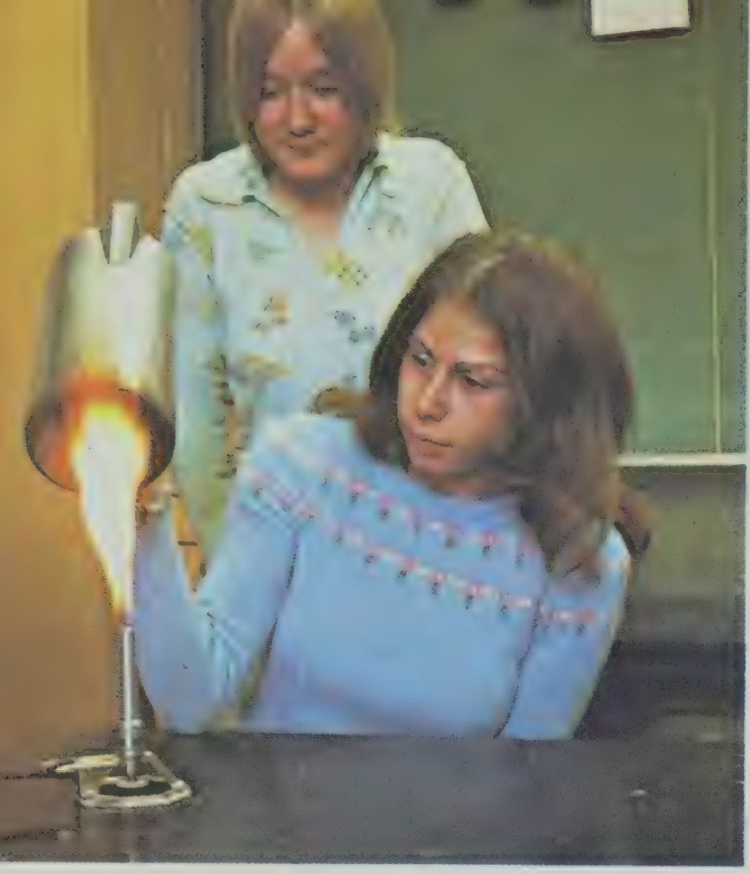


Fig. 70–1

These girls are finding out how the unburnt carbon forms on the bottom of the coffeepot. Why is the flame on the Bunsen burner yellow?

Common Pollutants in Air

Sulfur dioxide gas	SO_2
Carbon monoxide gas	CO
Nitrogen dioxide gas	NO_2
Nitric oxide gas	NO
Carbon soot (dust)	unburnt carbon (C)
Grinding dust	
Pollen from plants	
Radioactive fallout	

YOU NOW KNOW

- Our air is polluted by foreign materials.
- Pollution starts in homes and factories.
- Most pollutants come from some kind of fire.

6. WHERE DO POLLUTANTS GO?

You would expect pollutants to spread out all through the atmosphere. And they do! Winds blow them all over. Of course, until they spread, a blanket of pollutants remains around the place where they start.

Why do they not escape way up into the upper atmosphere so that they do not harm us? Some pollutants do. But you will remember that clouds form a blanket above our atmosphere. Clouds and fog trap the smoke and so we have smog. The temperature near the ground is low, and the smog is heavy. It cannot rise. The warm air above acts as a blanket to trap the smog. A new sharp wind or rain or a sudden change in temperature will then be able to break the smog. Meantime, there is danger!

7. WHAT ARE THE DANGERS OF AIR POLLUTION?

Experiments done in New York City show that each day thousands of tons of pollutants are dumped into the air. What are the results? In the first place, the amount of sunshine is lessened. This interferes with normal plant life and photosynthesis. Faces become dirty. Clothes drying on the line become dirty. Even beautiful statues and buildings become blackened and dirty. This results from impurities in the air.

When we turn to health, the story is even more alarming. Experiments have traced serious eye irritations and skin irritations to polluted air. Doctors now have strong evidence that

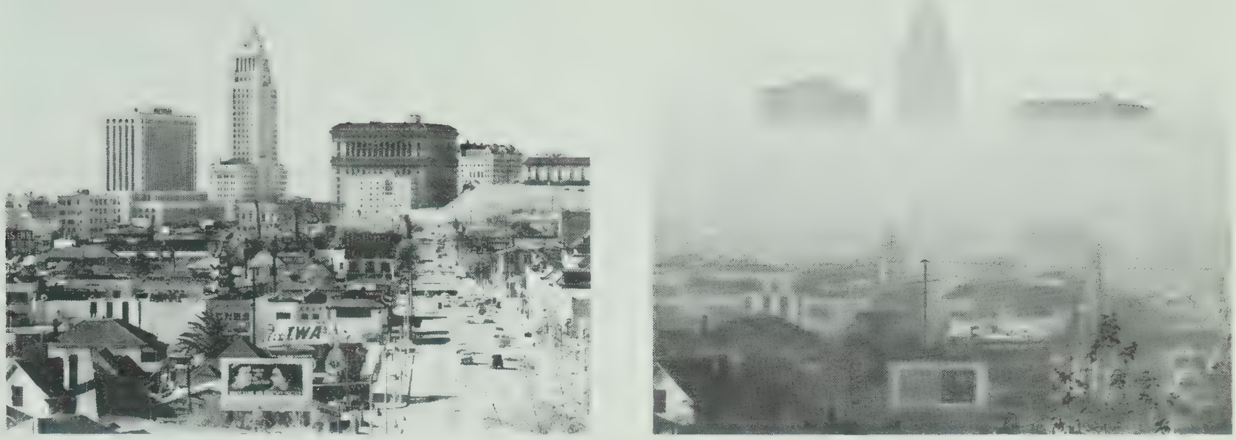


Fig. 71–1

The picture on the left shows Los Angeles on a clear day. The picture on the right shows the same place on a smoggy day. What caused the change?

air pollution may be one cause of lung cancer, asthma and bronchitis. When it is smoggy, many people suffer minor illness and discomfort in their nostrils and throats.

8. WINNING THE BATTLE WITH AIR POLLUTION

A knowledge of science can help beat air pollution. Scientists are now able to trace pollutants to know where they come from and where they go. This is a good first step. In addition, engineers are inventing ways to burn fuels more completely. Trapping the chemicals coming out of smokestacks and incinerators is another way of beating pollution.

The burning of fossil fuels (coal and petroleum) is the greatest source of dangerous pollution. Half of all SO_2 in the air comes from electrical generating plants which use coal and oil for power. Petroleum, which is made into gasoline, can be refined to lower its sulfur content. Also, there are some grades of coal which have a lower sulfur content than others. As you can see, we can reduce sulfur dioxide pollution by using low sulfur fuel. Natural gas, which contains little or no sulfur, is an excellent substitute.

Of course, the energy crisis of 1973 has speeded up our efforts to develop nuclear energy to drive our electrical generators. If we can develop nuclear reactors which do not produce dangerous radiation fallout, we will solve much of our pollution.

9. THE AUTOMOBILE: THE PLEASURE-POLLUTER

The automobile is one of the greatest sources of air pollution. It has been estimated that 3800 L of gasoline, burned in the internal combustion engine of a car, produces

60 kg of nitrogen oxides
4 kg of sulfur dioxide
1300 kg of carbon monoxide

What can we do about this?

As we saw above, there are some gasolines which are low in sulfur; many are low in lead. A change to this type of fuel is a good start. Again, learning from the 1973 energy crisis, we could move to smaller engine autos. Smaller engines (4 or 6 cylinders) and lighter-weight cars use less gasoline.

Most states and provinces now require new cars to have *anti-pollution devices* attached to the cars. One type is a *catalytic muffler*. Another kind uses an *after-burner*. This can ignite the unused carbon dioxide.

10. PERSONAL SAFETY FROM AIR POLLUTION

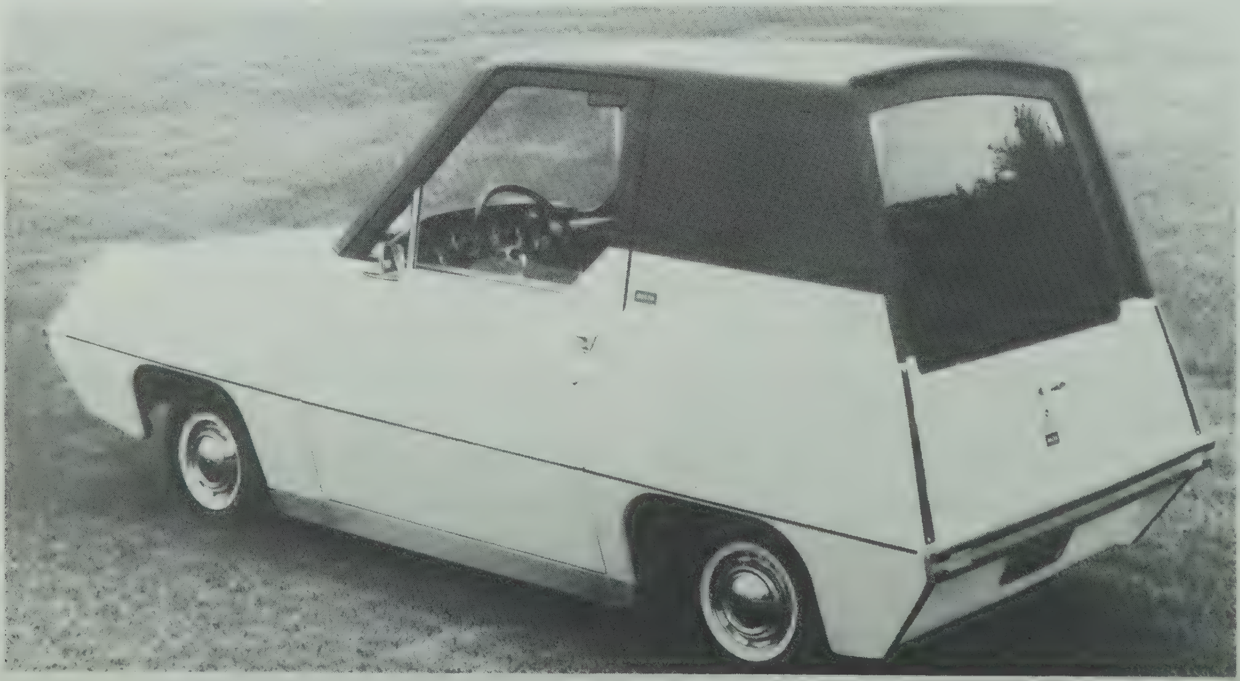
As we saw before, many cases of pollution come from burning gas. A few simple safety rules will protect you. Never run a car in a closed garage. The carbon monoxide gas, in tiny amounts, can cause death. Never stand behind an automobile exhaust where you can breathe in carbon monoxide fumes. A window should always be left open when riding in a car. The same rules apply in the home. When a gas or kerosene stove is burning, the room should be well ventilated. Windows should be open top and bottom. Oil burners, stoves and chimneys should be cleaned often.

YOU NOW KNOW

- Air pollution causes property damage.
- Air pollution is a possible cause of lung cancer, asthma, bronchitis and eye irritation.
- Pollution controls include filters, auto exhaust devices and trappings of chemicals in smokestacks.

Fig. 72–1

This experimental car is driven by an electric motor powered by special batteries. What are the advantages? What happens when the batteries lose their charge?



UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 10?

1. It is dangerous to cook on a gas stove.
2. Automobiles cause much air pollution.
3. Air pollution can be reduced.
4. Our air becomes dangerously polluted with gases and dusts.

II. Explanation please . . . answer in one or two sentences.

1. How do clouds and fogs increase the danger from air pollution?
2. How is smog formed?
3. How is poor combustion a cause of pollution?
4. Why should trash not be burned on public streets?

III. Knowing What and Why

1. Incomplete burning of gas
   a. makes more carbon dioxide.
   b. makes less water vapor.
   c. increases fogs.
   d. produces carbon monoxide.
2. The danger of carbon monoxide is especially great because
   a. it causes lung cancer.
   b. it has no color.
   c. it has no odor.
   d. respiration needs oxygen.
3. Ventilation in factories
   a. should let bad gases escape into the air.
   b. is not a problem.
   c. should be combined with pollution control devices.
   d. depends on combustion.
4. All of the following are air pollutants *except*
   a. sulfur dioxide.
   b. carbon monoxide.
   c. carbon dust.
   d. silver nitrate.

IV. Supply the missing letters.

Read the underlined letters downward. Get a food. *Do not write in this book.*

1. BELL___AR
2. D___W
3. DO___DRUMS
4. C___OUDS
5. OX___GEN
6. C___RBON
7. ___OLLUTION
8. EVA___ORATION
9. SEA___EVEL
10. SL___ET

V. For the Science Whiz

1. In Fig. 70–1, what difference would it make if you used a candle instead of the Bunsen burner? Why?
2. How are tunnels protected against pollution?
3. Why do some pollution control devices on autos use an extra spark plug in the tailpipe?

VI. For the Science Reporter

Contact your local health department or volunteer organizations. Ask for literature about *asthma, bronchitis* and *emphysema*. Report to your class on how air pollution is related to these diseases.

VII. Go and Discover

Visit a local gasoline station. Ask the mechanic to show you the antipollution device in a modern car. Ask him to explain why such cars need low-lead gasoline.

Glossary:
What Does It Mean?

Aeolus	EE-o-lus	The god of the winds in mythology.
after-burner		A device used in automobiles to burn unburnt CO to CO_2.
altimeter	al-TIM-e-tur	An instrument used to measure height; usually an aneroid barometer.
altitude		The height of an object above sea level.
aneroid	AN-uh-roid	A barometer which works without the use of liquids.
Antarctic Circle		The line of latitude of 66.5° south of the equator.
Arctic Circle		The line of latitude 66.5° north of the equator.
barometer	buh-ROM-e-tur	An instrument used to measure air pressure.
catalytic muffler		A device used on automobiles to trap particles by electrical charge.
calm		An area with very little air movement.
cirrus	SIR-us	A type of cloud which forms at high altitudes and looks feathery.
cloud		A visible mass of water or ice particles in the atmosphere.
compressed	kom-PREST	Squeezed into a smaller space. Example, compressed air.

conduction	kon-DUK-shun	The transfer of energy such as heat through a substance (solid, liquid or gas) without movement of the substance.
convection	kon-VEK-shun	The transfer of heat through fluids.
cumulonimbus	KYU-mu-lo-NIM-bus	A type of cloud which is heavy with rain or snow. Also called a thunderhead.
cumulus	KYU-mu-lus	A thick, fluffy cloud which is seen during fair weather.
current	KUR-rent	The flow of water or air in a certain direction.
dew		Drops of water caused by condensation.
dew point		The temperature at which the water vapor in the air condenses to form dew.
diaphragm	DY-a-fram	The tissue between the chest cavity and the abdominal cavity needed for breathing.
doldrums	DOL-drumz	The belts of light wind near the equator.
equator	ee-KWAY-tor	An imaginary line running east and west around the middle of the earth.
evaporate	ee-VAP-or-ate	To change from a liquid to a gas.
fog		A cloud which has formed close to the ground.
frost		Ice formed on plants or the ground when the dew point is below freezing.
Galileo	gal-i-LAY-o	An Italian scientist and teacher.
greenhouse		A glass building where plants are grown year-round.
Guericke, Otto von	GER-i-kee	A German scientist who developed the Magdeburg Hemispheres.
hemisphere	HEM-i-sfeer	The northern or southern half of the earth divided by the equator.
horse latitudes		Belts of high pressure areas 30° north and 30° south of the equator.

humidity	hyou-MID-i-tee	The amount of water vapor in the air.
inversion	in-VUR-zhun	A layer of cold air in the upper atmosphere traps the warm air below it.
latitude		Location measured in degrees north or south of the equator.
pollutant	po-LOO-tant	Any foreign material in air or water, such as soot or dust.
pollution	po-LOO-shun	Air or water in an unclean state.
precipitation	pree-SIP-i-TAY-shun	Moisture that falls from the air as rain, snow, sleet or hail.
radiant energy	RAY-dee-ant	Energy that is sent in waves from the sun.
radiation	ray-dee-AY-shun	The transfer of heat by energy waves.
refract		To bend, such as a ray of light as it moves from one optical medium to another.
relative humidity		How much water the air holds compared to how much it can hold at a given temperature.
saturated	SATCH-you-ray-ted	When the air can hold no more water vapor.
siphon	SY-fun	A tube used for moving water from a higher to a lower level by air pressure.
smog		A combination of smoke and fog.
solar batteries		Batteries charged by special cells using energy from the sun.
solar reflectors		Special metal plates used to capture the sun's rays for heating.
soot		The unburned carbon particles in the form of a fine dust.
stratus	STRAT-us	A type of cloud that forms in layers. Rain usually follows.
sun		The star that is the center of our solar system around which the planets revolve.
temperature		The degree of heat of an object.
thermometer	thur-MOM-uh-tur	An instrument for measuring temperature.

Torricelli	tor-i-CHEL-ee	A student of Galileo. He invented the mercury barometer.
trade winds		Winds which blow constantly toward the equator from the horse latitudes.
Tropic of Cancer		The imaginary line 23.5° north of the equator.
Tropic of Capricorn		The imaginary line 23.5° south of the equator.
vacuum	VAK-you-um	A space with nothing in it.
water cycle		The continuous evaporation and condensation of water in our atmosphere.
westerly winds		The winds that blow from the west.
wind		The approximately horizontal movement of the lower air caused by unequal heating of air masses.

UNIT III

The large satellite ESSA (lower right) is named after the Environmental Science Service Administration. It is sending back pictures of cloud formations to the National Weather Service. The pink balls above the bottom part of the earth are weather balloons. The Nimbus satellite (center right), the hurricane plane (top left) and the boat (lower left) are other ways by which weather conditions around the world are collected by the Weather Service. The radar station (middle left) receives and relays the information to every part of the earth. It is used to analyze the weather. The part of the earth shown is India.

PREDICTING THE COMING WEATHER

UNIT III

Predicting the Coming Weather

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11

TARGET
Who cares about the weather?

Knowing About Weather

1. WHO CARES ABOUT THE WEATHER?

Who cares? You and all the millions of people who listen to the radio or read the weather report in the newspaper care! Why do you care? Your health depends on dressing properly for the weather outside. Your father may want to know whether to drive or to take the bus. Your aunt may not be able to take the plane home. The Expos may be rained out in Montreal. The farmer in Ohio may change his plans for harvesting. Our recreation, our health, our safety and many occupations depend on the changes in weather.

2. THE WEATHER REPORT

Today's Forecast

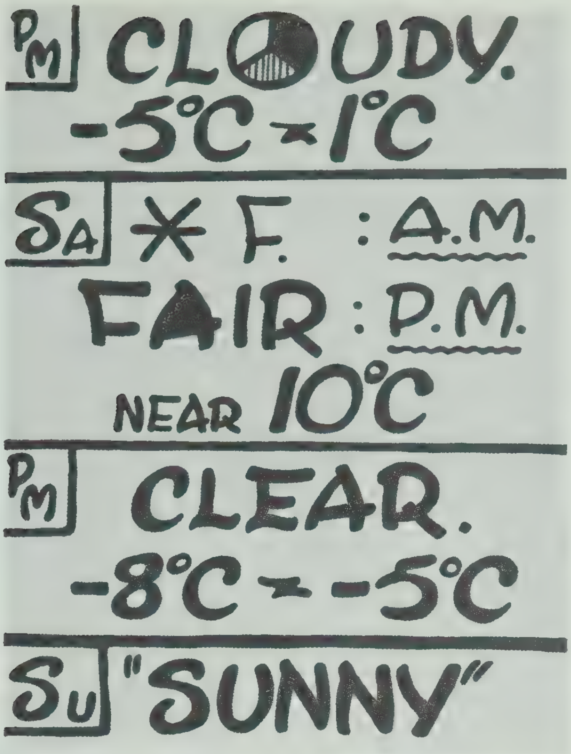
NEW YORK CITY—Light rain or drizzle today, ending tonight. High today in the low teens, winds from the east to southeast at 15 to 30 km/h; low tonight in the 4 to 6°C range. Mostly cloudy with a chance of a few showers tomorrow. Precipitation probability 80% today and tonight and 30% tomorrow.

Five-Day Forecast

(January 25 through January 29)

NORTHEASTERN NEW YORK INCLUDING BUFFALO, AND SOUTHERN ONTARIO, INCLUDING TORONTO AND HAMILTON — Temperatures during the period tomorrow through Wednesday are expected to average near normal with daytime highs of 0 to 4°C and lows of −5 to −2°C. A chance of showers Saturday and Sunday.

A weather report tells what the weather is going to be like today, tomorrow, and possibly for the following five days. In addition to this report, there is a summary of weather for the full 24 h of this day. There is also a brief listing of the weather in many large cities. Finally, there is a weather map. Both radio and TV stations usually broadcast weather summaries. In



PM CLOUDY.
-5°C ~ 1°C
SA * F. : A.M.
FAIR : P.M.
NEAR 10°C
PM CLEAR.
-8°C ~ -5°C
SU "SUNNY"

Fig. 83–1

These reports are weather PREDICTIONS (pree-DIK-shunz). Another word for prediction is FORECAST (FOR-kast).

most cities, you can dial a special telephone number to get a summary of the weather.

3. WHAT IS WEATHER?

The weather report describes conditions of the atmosphere. It is really telling about the changes from day to day. As you know, these conditions may even change several times in one day. The table below lists the elements of the weather.

WEATHER ELEMENTS

Air pressure
Air temperature
Relative humidity
Wind velocity (speed)
Wind direction
Precipitation
Appearance of sky

We can now say that weather is the short-range condition of the atmosphere with regard to heat, pressure, winds and moisture.

4. WEATHER PREDICTION IS A SCIENCE

"Onion's skin very thin:
Mild winter coming in."

"When eager bites the thirsty flea,
Clouds and rain you sure shall see."

These pleasant old sayings may or may not be true. But you can be sure they are not exact. Predicting the weather means precise measurement of the conditions of the atmosphere. It means that we apply our knowledge of science. Weather prediction is the science of METEOROLOGY (mee-tee-oh-ROL-oh-jee). Your "weather man" is a METEOROLOGIST (mee-tee-oh-ROL-oh-jist).

YOU NOW KNOW

- Weather study is the science of meteorology.
- Weather is the short-range changes in seven elements of our atmosphere (Paragraph 3).
- Weather and its prediction are important to everyone.

5. WHO PREDICTS THE WEATHER?

Actually, anyone can predict the weather. Private citizens, if they collect scientific facts carefully, can make some accurate predictions. The

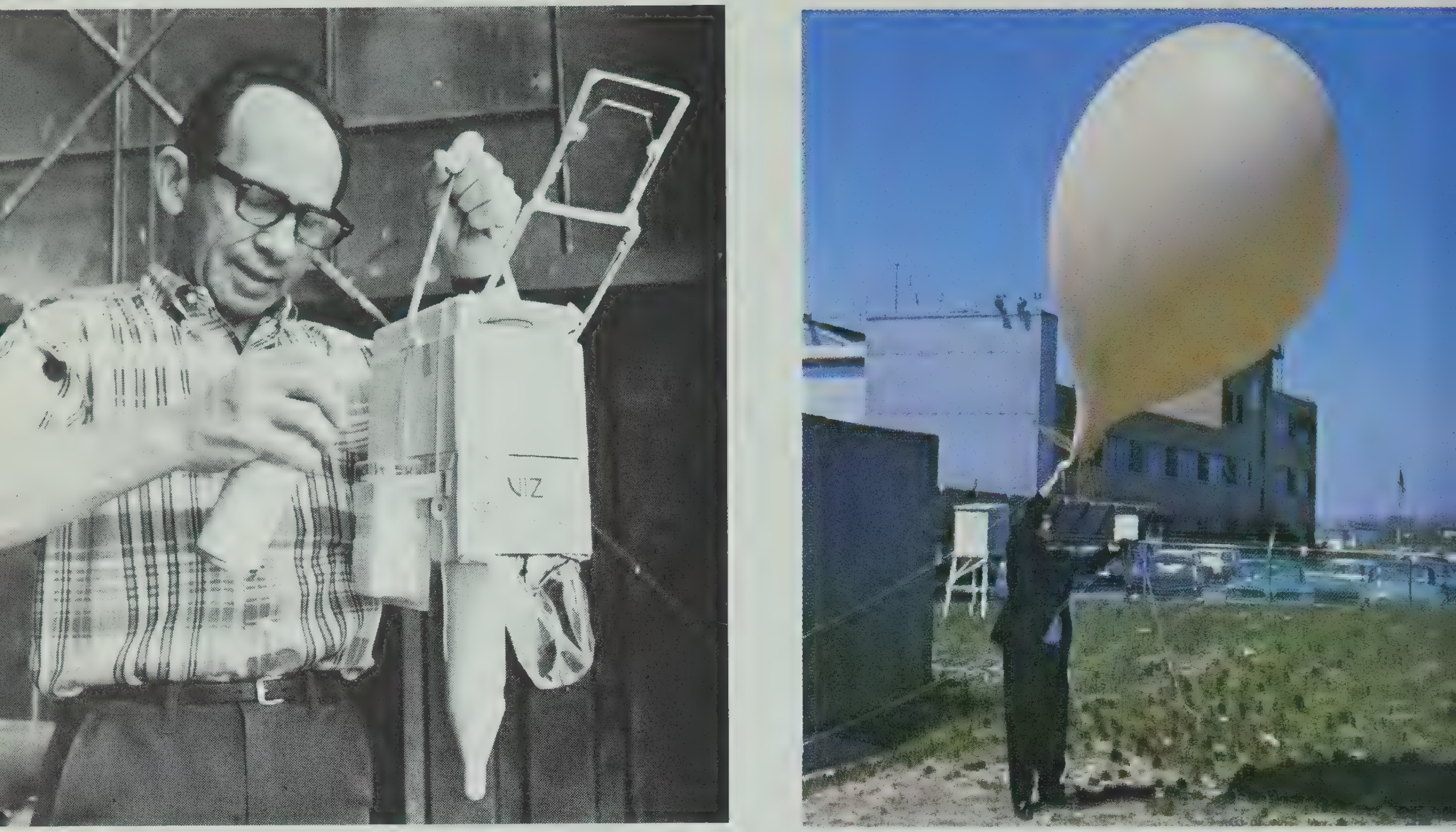


Fig. 84–1

Instruments carried aloft help us predict weather. In the picture on the left, a man is getting such an instrument prepared. On the right, a balloon which will carry the instrument aloft is being readied for flight.

problem is that you must be able to collect these facts from many places in the country. You must be able to get facts about the upper atmosphere. This requires expensive equipment. There are some private companies that can do this, for example, the airlines. But the most accurate weather forecasts in our country are made by the National Weather Service.

6. EARLY DAYS OF WEATHER PREDICTION

Ancient Greeks, including the scientist Aristotle, tried to predict the weather. They used folklore, simple observations and other nonscientific means. Scientific prediction began when the proper scientific instruments were developed. As you saw, Torricelli invented the barometer and Galileo invented the thermometer. Soon other instruments were invented. We shall study these later.

It is not enough to have instruments. We must also be able to examine the upper atmosphere. You have heard of Benjamin Franklin's famous kite experiment. Other people of his day tied thermometers to kites. The kites took the thermometers aloft to find out the temperatures high in the air. The kite was followed by balloons. After balloons, came airplanes.

Now rockets and satellites do the job.

So far, two problems (air pressure and temperature) were solved. But these two can only tell you about weather in the immediate neighborhood. Since we know that the air moves, we must be able to know what is happening in other parts of the country, or in other parts of the world. We need to communicate these readings to some central point. The telegraph (invented in 1844), the telephone and the radio have all filled this need. Now we have seen all the requirements for weather prediction.

Needs for Weather Prediction

1. Accurate instruments
2. Reaching upper atmosphere
3. Communication of data

7. THE NATIONAL WEATHER SERVICE

The U.S. Department of Commerce includes the *National Oceanic and Atmospheric Administration* (NOAA). NOAA conducts the *National Weather Service*. The National Weather Service consists of over 600 *weather stations*. Weather stations collect readings from instruments four times each day. They send these figures to central stations for study. The central station predicts the weather and prints the weather maps. In Canada, Environment Canada does this job.

YOU NOW KNOW

- There are three needs for accurate weather prediction: good instruments, a way to take these instruments aloft and a way to communicate all readings to a central place.
- The national weather service predicts weather and issues reports.

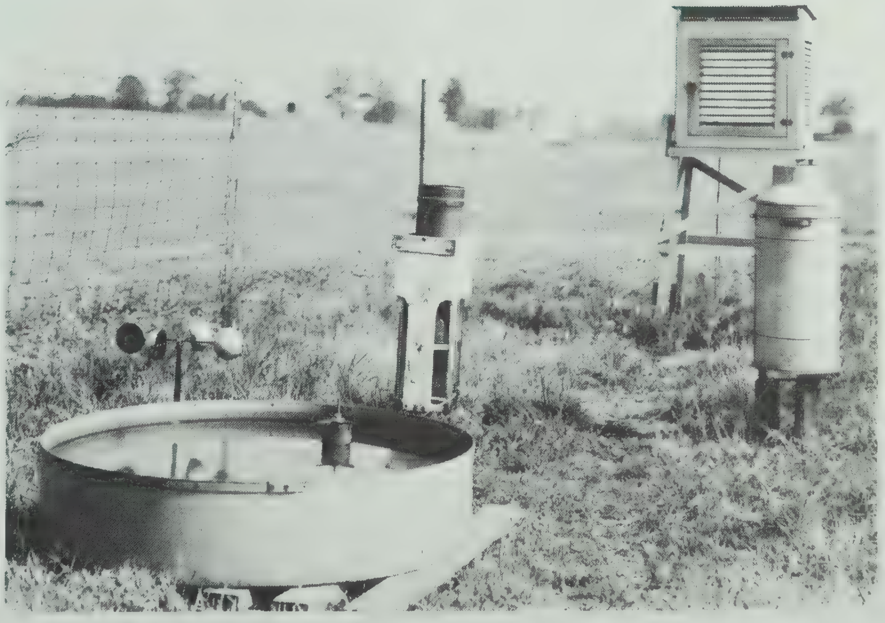


Fig. 85–1

This is one of the many weather stations in existence. Can you identify the various instruments shown?

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 11?

1. Weather prediction is a science.
2. The weather bureau predicts weather.
3. Not all weather can be predicted.
4. Weather prediction requires instruments and communication.

II. Explanation, please . . . answer in one or two sentences.

1. What are the elements that make up the weather?
2. What is NOAA?
3. Why does communication make for better weather prediction?
4. Who benefits from weather predictions?

III. Knowing What and Why

1. Weather instruments are used to measure the upper atmosphere because
   a. the instruments tell "central" what's happening.
   b. barometers are more accurate aloft.
   c. our weather is formed in the atmosphere.
   d. airlines can do predicting.
2. The national weather service
   a. predicts weather and prints weather maps.
   b. predicts weather and controls pollution.
   c. operates radar and controls pollution.
   d. prints almanacs and controls crops.
3. Weather concerns itself with
   a. short-range changes in the atmosphere.
   b. climate and tides.
   c. radio and TV effects.
   d. rainfall, snows and storms only.
4. Weather elements include heat, pressure, winds and
   a. radiation.
   b. moisture.
   c. cosmic rays.
   d. tides.

IV. On the Ladder of Understanding Chose the correct number or phrase from the parenthesis to complete the sentence.

1. Air pressure at sea level is (100, 98, 50) kPa.
2. The highest relative humidity of the three is (16%, 60%, 94%).
3. Water freezes at (0°C, 100°C, 32°C).
4. A westerly wind comes from the (west, east).
5. Clouds are most like (sleet, snow crystals, fog).
6. Precipitation does *not* include (rain, dew, hail).
7. Warm air is (lighter and wetter, heavier and colder) than cold air.
8. Relative humidity depends on (how much moisture is in the air, how fast winds are blowing).

V. Brain Teasers

1. Why are old-fashioned weather sayings sometimes true?
2. Why does a meteorologist have to understand chemistry and physics?

VI. For the Amateur Scientist

1. Start a collection of weather maps. Cut them out of the newspaper. Keep them for a full month. Each day, compare the prediction with the actual weather.
2. For a free booklet on weather, write to NOAA, Washington, D.C., or to Environment Canada, Ottawa, Canada K1A 0S5.

12

TARGET
What instruments are used to predict the weather?

The Tools of the Meteorologist

Fig. 87–1

The weather vane shows us the direction of the wind.

1. LOOKING BACK . . .

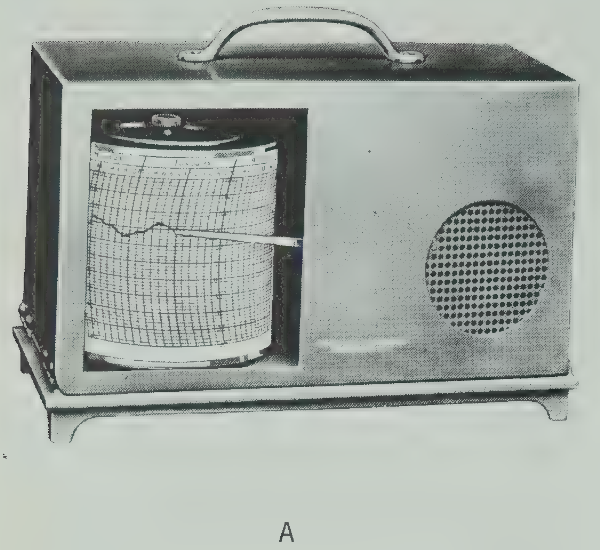
The four main factors in our weather are heat, air pressure, winds and moisture. Weather experts need instruments to study these four factors. They not only have to study these factors near the earth, they must study them in the upper atmosphere. They not only have to know what is happening nearby, they must also know what is happening in other parts of the country. Let us see how the weather experts use their scientific tools.

2. THE HEAT OF THE ATMOSPHERE

Thermometers record changes in heat. We call this the temperature and we measure it in *degrees*. In most of the world, weather is reported in degrees Celsius. While home thermometers may use alcohol in the glass tube, more precise thermometers use mercury or hydrogen gas.

CELSIUS SCALE

Freezing point of water	0°C
Boiling point of water	100°C
Degrees between boiling and freezing	100°C



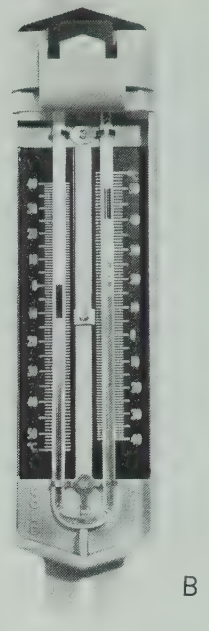


Fig. 88–1

A The thermograph (left) records rise and fall in temperature. **B** The Maximum-Minimum Thermometer shows the highest and lowest temperature for a given time.

Since the temperature changes many times during the day, weathermen must take readings every hour. Does this mean that they must be on duty 24 h every day? No!

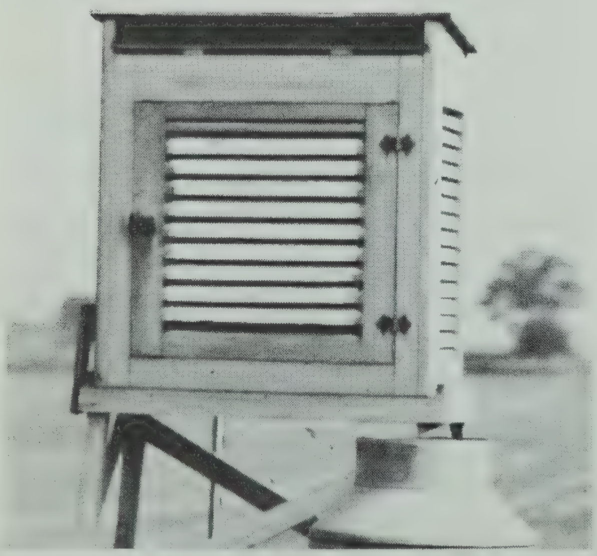


Fig. 88–2

Can you explain why thermometers in weather stations are put in these small houses?

An instrument known as the THERMOGRAPH (THERMO-graf) can do it. Fig. 88–1 A shows that a thermograph has a seven-day clock. The drum rotates and the moving pen writes down the rise and fall of the temperature. In this way, a meteorologist need not watch the thermometer all the time. Another very interesting thermometer is the one in Fig. 88–1B. The steel pin shows the lowest temperature in the left tube. The pin in the right side shows the highest temperature. Ask your teacher to show you how this works.

3. RECORDING CHANGES IN AIR PRESSURE

The mercury or aneroid barometer records changes in air pressure. As you learned before, air pressure is measured in newtons per square

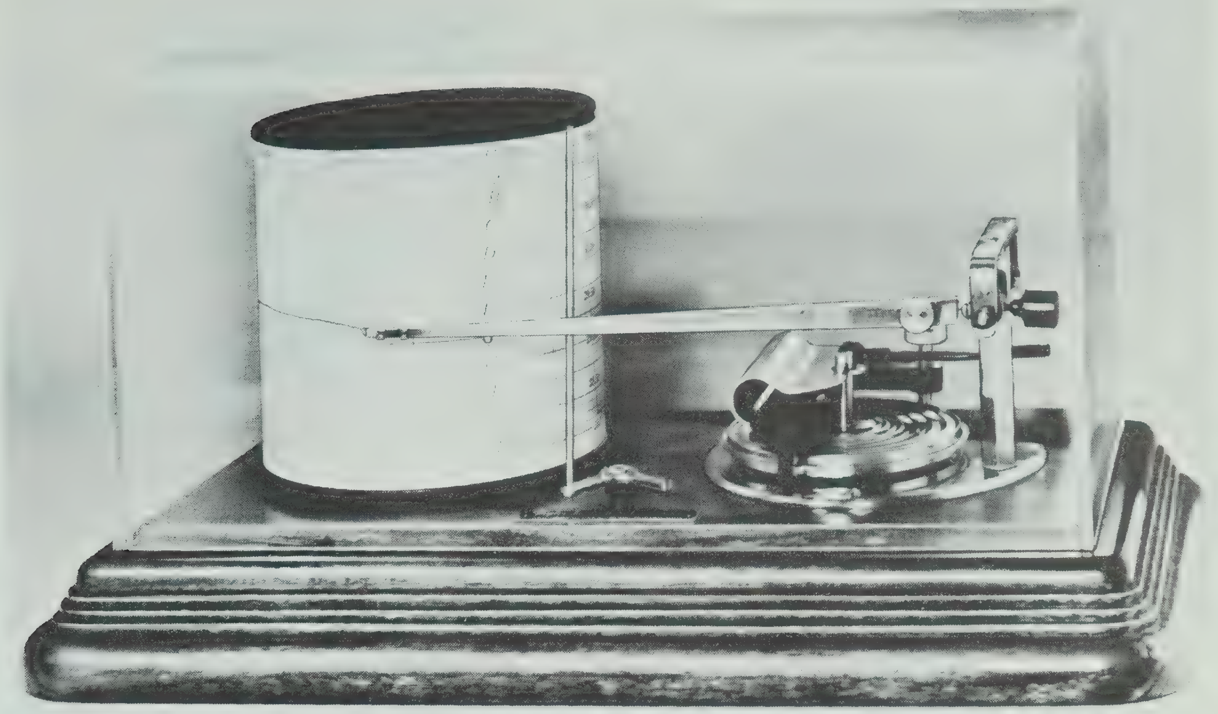


Fig. 89–1

The barograph is an aneroid barometer with a seven-day clock to rotate a drum. Why does the graph show a wavy line?

metre, or pascals. Look at a weather map. It probably records pressure in pascals. Of course, we must remember that readings at sea level are higher than on mountains. Suppose the meteorologist is busy and cannot keep watching the barometer? What does he do? Easy! He uses the BAROGRAPH (BAR-o-graf).

4. WINDS: WHERE AND HOW FAST?

Winds are horizontal layers of moving air close to the surface of the earth. As the air moves, it brings changes in temperature and moisture. It is important, therefore, to know where the wind is coming from and where it is going. Look at the weather vane at the beginning of the chapter. This is a familiar sight on church steeples, towers and flagpoles. The tail of the arrow is always larger than the head. As the vane spins, the head, or arrow, points in the direction *from* which the wind is coming. In the picture, the arrow points south. The wind is coming *from* the south. It is a southerly wind.

We must also know how fast the wind is moving. To measure wind speed, we use the ANEMOMETER (AN-uh-MOM-e-tur). It is made of three cups that catch the wind; the wind spins the cups. The faster the wind, the faster the cups spin. The spinning shaft is connected to a meter that shows the speed in kilometres per hour.

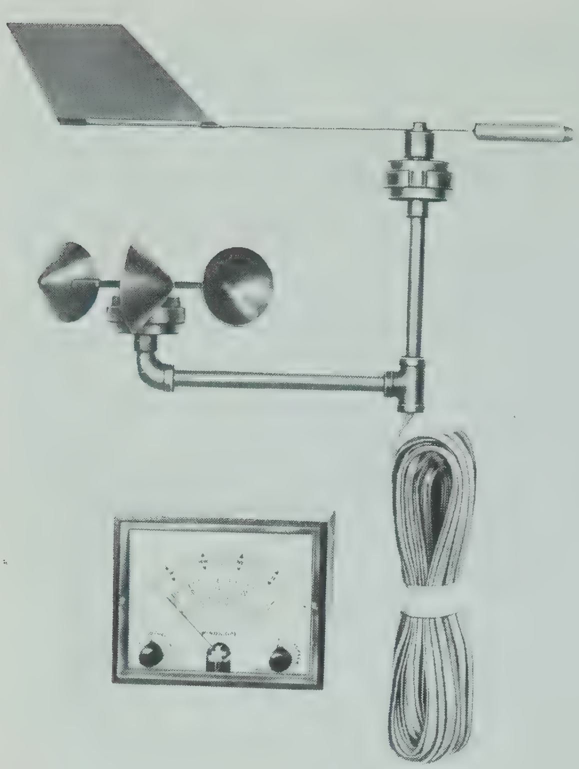


Fig. 90–1

How is an anemometer used to predict weather?

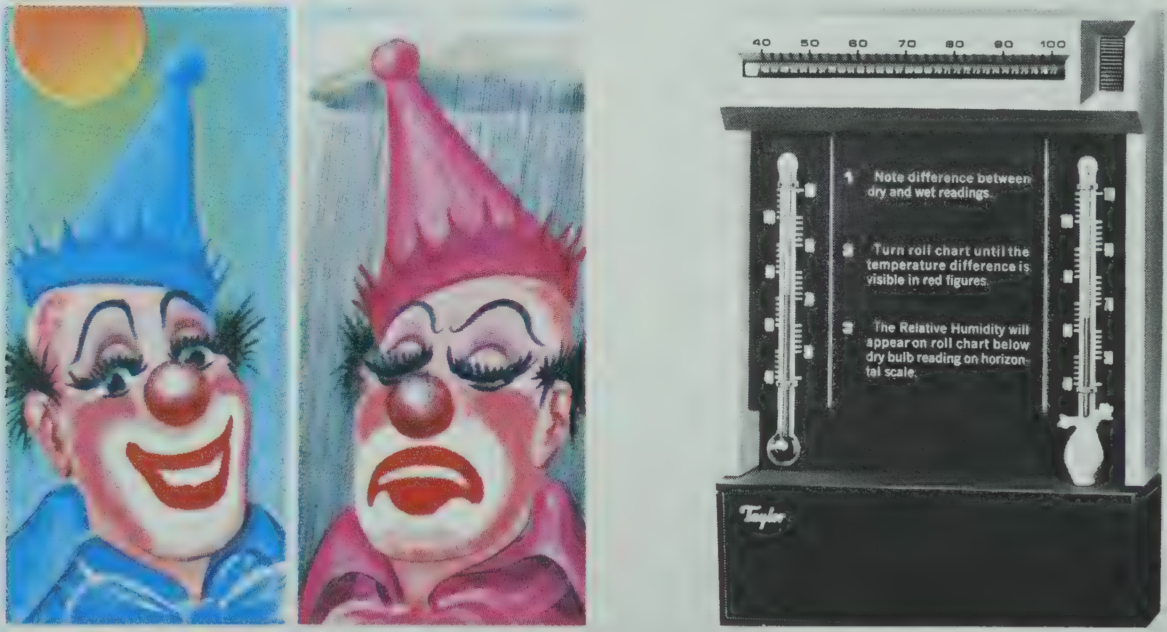
5. MEASURING HUMIDITY

The clown's cap in Fig. 90–2 is blue when the air is dry. It is pink when the air is wet. His cap has been painted with the chemical, cobalt chloride. A girl knows that her hairdo comes apart when the humidity is high. But these two methods are really not accurate ways of measuring humidity. They do not measure amounts of moisture.

There is an instrument called the HAIR HYGROMETER (hy-GROM-e-tur) which uses a few strands of human hair to measure moisture. The hairs are connected to a dial. As the hairs get wet, they get longer; as they dry, they get shorter. The dials tell the moisture in *percent*. There are also other instruments to measure relative humidity.

6. MEASURING RAINFALL

"Yesterday 20 mm of rain fell." How did they know? The RAIN GAUGE (GAYJ) collects water and the ruler measures the height in millimetres.



1 Note difference between dry and wet readings.

2 Turn roll chart until the temperature difference is visible in red figures.

3 The Relative Humidity will appear on roll chart below dry bulb reading on horizontal scale.

Fig. 90–2

Explain why the clown's cap changes color. The instrument on the right is a dry-bulb, wet-bulb thermometer. It is also used for measuring humidity.

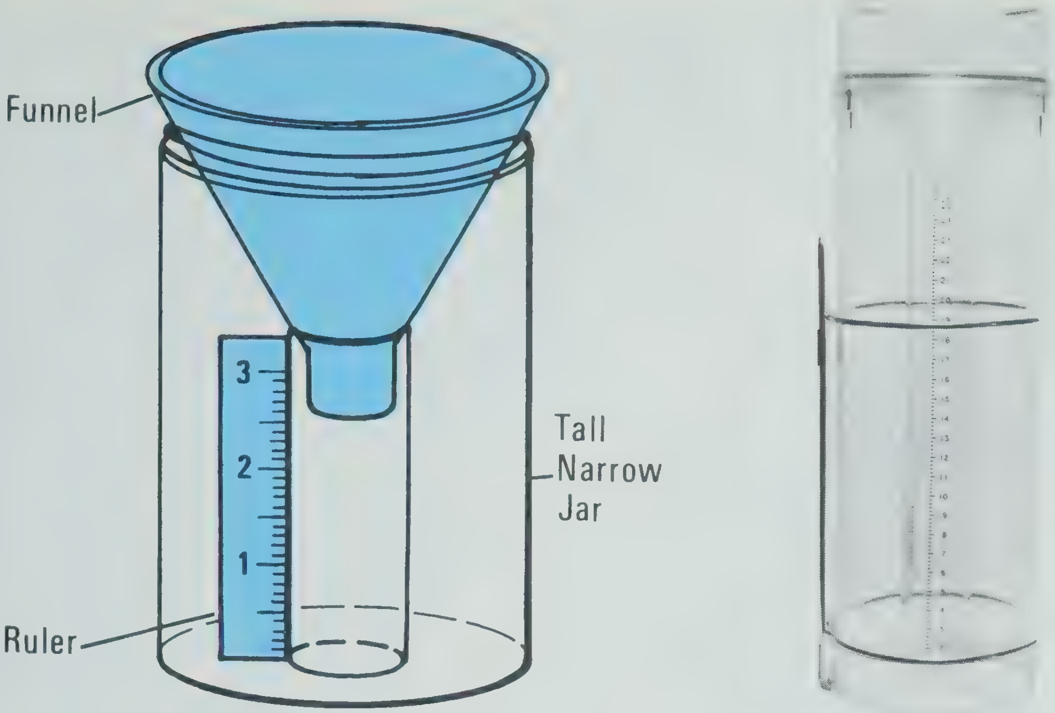


Fig. 91–1

Rainfall is measured in millimetres. You can make a rain gauge like the one on the left.

You can make the homemade rain gauge as in Fig. 91 – 1. The one at the right is used by weather stations. You might like to know that 10 cm of snow equals 10 mm of rain. Why is this possible?

7. UP, UP AND AWAY!

Modern weather stations send instruments aloft to measure conditions and report back to earth. The *radiosonde* carries instruments to about 25 km above earth. A radio records the readings of the instruments and sends them back to the weather station. At a very high altitude, the balloon bursts and the instruments float back to earth on a little parachute.

Pilot balloons, filled with helium, are sent aloft. Their path is watched through a special telescope to track the direction and speed of upper winds.

8. WEATHER SATELLITES

In 1960, the U.S. launched the first weather SATELLITE (ESSA 1) into the atmosphere. Artificial satellites orbit (circle) the earth in its atmosphere. They carry many kinds of instruments which measure temperature and rays. This information is sent back to weather stations on earth. They also send back cloud pictures by day and night. Weather satellites get their power from special batteries charged by the sun.

Weather satellites operate on a worldwide and local basis. The newest satellites are called TIROS (TEE-rus), NIMBUS (NIM-bus), and GOES. A typical satellite is about 100 × 100 × 125 cm and weighs about 185 kg.

Fig. 92–1

Modern instruments go aloft to send back information about the atmosphere.

YOU NOW KNOW

Summary of Weather Instruments

Instrument	Tells
weather vane	wind direction
anemometer	wind speed
hygrometer	humidity
barometer, barograph	air pressure
thermometer, thermograph	air temperature
rain gauge	precipitation
radiosonde, Rawin Tiros I Nimbus A Essa 7	upper atmospheric conditions

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 12?

1. Meterologists use accurate weather instruments.
2. The most important weather measurements are for temperatures.
3. Modern weather predictors send instruments high up in the atmosphere.
4. Weather satellites work with TV cameras.

II. In which paragraph do you find the answer?

1. Why is a self-recording instrument a big help to a meterologist?
2. What are pascals?
3. In what units is humidity measured?
4. How are quantities of snow and rain measured?

III. Knowing What and Why

1. A hair hygrometer works on the idea that
    a. the hair changes length with moisture.
    b. springs measure condensation.
    c. cobalt chloride affects the hair.
    d. temperature affects humidity.
2. A rain gauge measures
    a. precipitation in percentage.
    b. humidity in percentage.
    c. condensation in pascals.
    d. rain in millimetres.
3. Tiros and Nimbus are the names of
    a. clouds.
    b. wind belts.
    c. weather satellites.
    d. humidity instruments.
4. To know how a wind will affect our weather, we must know
    a. its speed and direction.
    b. its relative humidity.
    c. where it started.
    d. how much dust it is carrying.

IV. Understanding the Diagrams

1. In Fig. 90—1, what does the face of the meter show?
2. In Fig. 88—2, why is the housing painted white?
3. In Fig. 88—1B, suppose you kept the instrument in an incubator set at 21°C. What would the two thermometers show? Why?
4. In Fig. 87—1 of the weather vane, if the arrow pointed to the E, what would it mean? Explain.

V. Match the instruments with the units.

INSTRUMENT	UNIT
1. Thermometer	a. pascals
2. Altimeter	b. metres
3. Hygrometer	c. amperes
4. Rain gauge	d. percentage
5. Anemometer	e. millimetres
6. Barograph	f. volts
	g. degrees
	h. km/h

VI. For the Math and Art Whiz

Draw a line graph to show the following on one graph (2 colors). Bring it to class.

	Barometer	Thermometer
Sunday	100.0 kPa	20.0°C
Monday	99.6 kPa	20.0°C
Tuesday	99.2 kPa	21.0°C
Wednesday	99.0 kPa	21.0°C
Thursday	99.9 kPa	21.6°C
Friday	100.2 kPa	20.0°C
Saturday	100.1 kPa	18.0°C

13

TARGET
How is our weather born?

Air Masses and Air Fronts

Fig. 94–1

How did Benjamin Franklin explain the nature of lightning?

1. FLOATING MASSES IN OUR OCEAN OF AIR

Our troposphere is a huge ocean of air. It is from 6 km to 18 km high. But its temperature and its humidity are not the same all over. There are small "islands" of air that float in the larger troposphere. These smaller sections are called *air masses*. How are air masses formed?

They are formed by "standing still" over a given part of land or over an ocean for, let us say, several weeks. While they are "standing still," they become changed by their environments. Therefore, the temperature and humidity of an air mass resemble the earth or the waters below it. Air masses may be a few kilometres high and cover large areas, possibly as big as several states put together.

2. THE FAMILY OF AIR MASSES

Each air mass is very large. Its temperature and its moisture are the same throughout for the whole air mass. Scientists have recognized air masses according to where they are formed. Look at the map, Fig. 95–1.

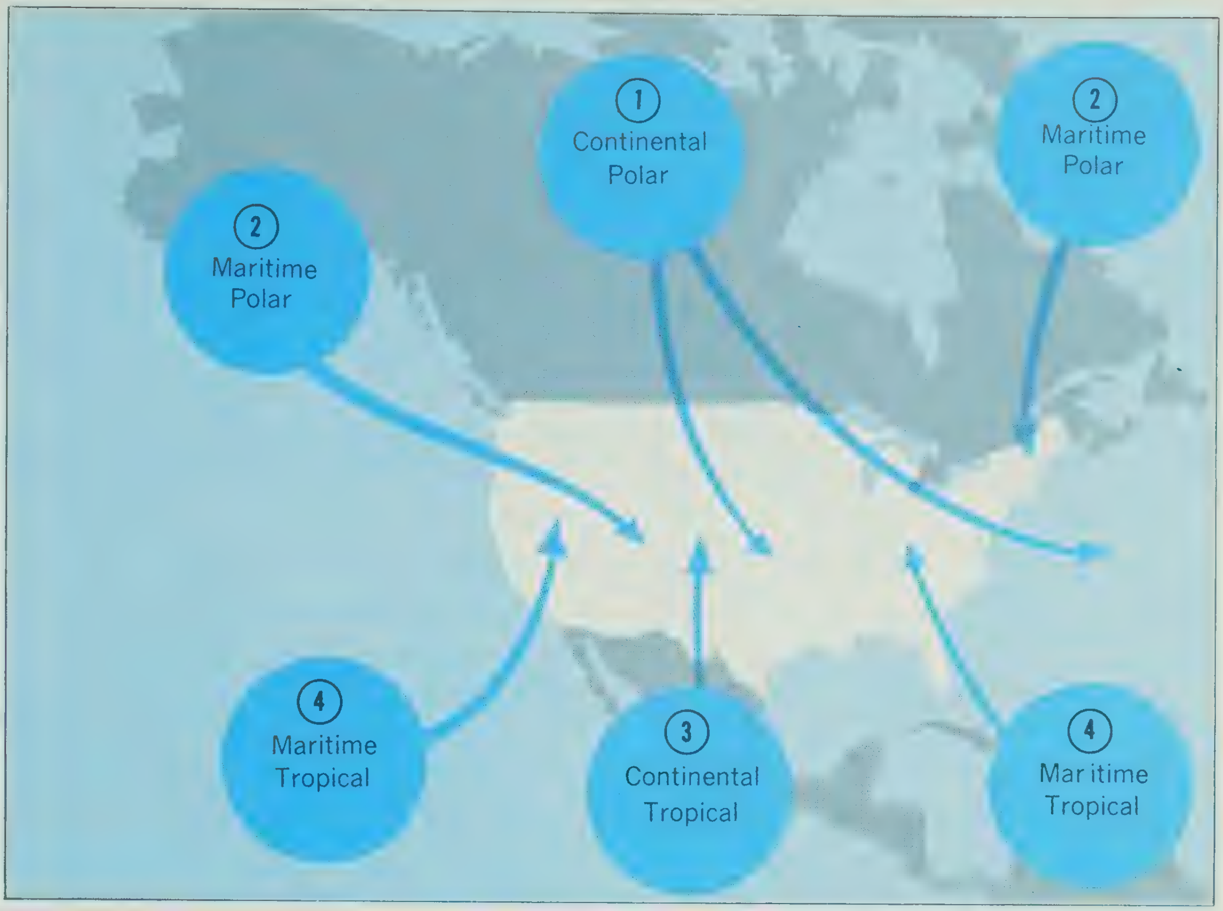


Fig. 95–1

These air masses help form the weather of North America.

One kind of air mass is formed near the poles; the other kind is formed near the tropics. The air masses formed near the poles may be formed over land (over the continents). We call these *continental polar masses* (1). Also in the north, near the poles, some air masses are formed over the oceans. We call these *maritime polar masses* (2).

Down south, near the tropics, some air masses are formed over land (over the continents). These are *continental tropical masses* (3). Other air masses are formed over the sea. These are *maritime tropical masses* (4).

The map shows you that the main sources of air masses in North America are in the north-central part of Canada, the Pacific Ocean, the north of Mexico and the Atlantic Ocean.

3. WARM OR COLD? DRY OR MOIST?

Look back in Paragraph 1. There we learned that the temperature and humidity of an air mass resemble the earth below it or the waters below it. If an air mass is formed over water, it absorbs water vapor—it is moist. If the air mass stands over land, it absorbs little moisture—it is dry. If an air mass stands over a cold area, it absorbs little heat—it is cold. If the air mass stands over a hot area, it absorbs heat—it is warm. Knowing the *source* of an air mass tells us a great deal about it.

THE FOUR FAMILIES OF AIR MASSES
WHICH CONTROL NORTH AMERICAN WEATHER

Name	Sources	Description
Continental Polar (1)	North-Central Canada	Dry, Cold
Maritime Polar (2)	North Pacific, North Atlantic	Moist, Cold
Continental Tropical (3)	Mexico, Southwest U.S.	Dry, Warm
Maritime Tropical (4)	Caribbean Sea, Gulf of Mexico, Central Pacific and Atlantic	Moist, Warm

4. WHERE DO AIR MASSES GO?

Air masses do not continue to stand still. The earth's rotation and gravity begin to "spin" them and move them. The Radiosonde, the Rawin and other instruments have traced the path of air masses. Their speed and direction are pretty well known. Look at the arrows in Fig. 95–1. These are the usual directions of the air masses. You can see that the polar air masses (1 and 2) move from north to south and turn to the east. The tropical air masses (3 and 4) move from south to north and turn to the east.

Fig. 96–1
Meteorologists gather facts about air masses from satellites.

YOU NOW KNOW

- An air mass is a large body of air in the troposphere with the same temperature and humidity throughout.
- Our troposphere is made up of several families of air masses.
- Air masses are warm or cold; dry or moist; depending on where they were formed.
- Air masses move in known directions.

5. WHEN AIR MASSES MEET

As air masses move, they change. Why? Look at Fig. 95–1. The Maritime Polar Mass (No. 2) is over the water of the Pacific. It is cold and moist. It begins to move over the land. Of course, it will become warmer. This is true for all air masses. As they move, they change.

When different air masses meet, they may cross each other's paths. There is a "battle"; as in any army there is a *front*. A front is the boundary between two unlike air masses. As these fronts are formed and move, they cause changes in weather. Air masses do not mix. Let us try to understand fronts.

If a cold mass meets a warm mass, the cold air pushes the warm air forward. The cold air pushes itself *under* the warm air, and the warm air moves *over* the cold air. This is a *cold front.*

When a warm air mass follows a cold air mass, it pushes the cold air forward. The warm air moves *over* the colder, heavier air. This is a *warm front.* If neither the cold air mass, nor the warm air mass moves, we have a *stationary front.*

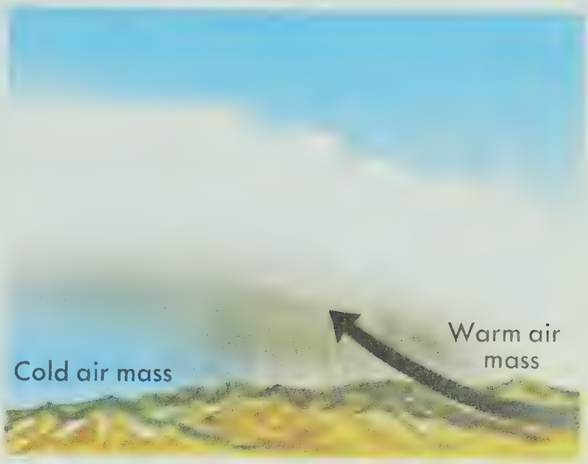


Fig. 97–2
A warm front.

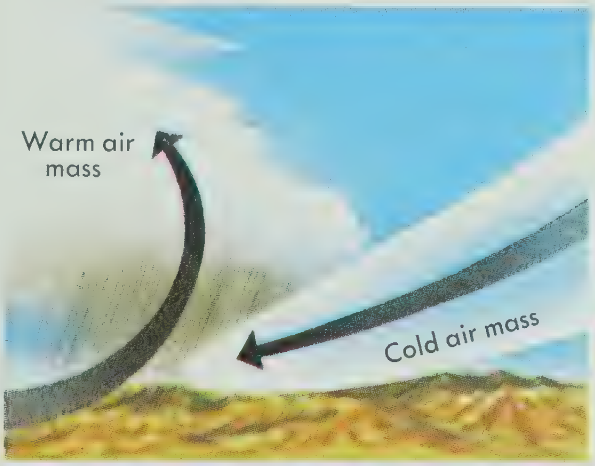


Fig. 97–1
A cold front.

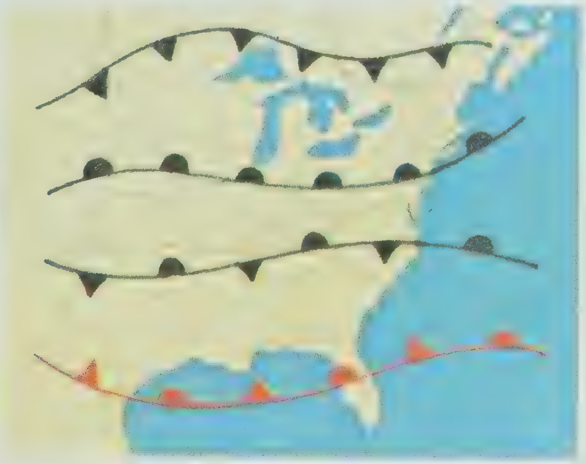


Fig. 97–3
These symbols are used on weather maps. What do they mean?

6. FRONT WEATHER

All fronts generally move from the west to the east. As the fronts move, they bring weather changes. Warm fronts may be 1600 km long and about 800 km wide. Cold fronts are much smaller. Both types of fronts bring weather changes.

7. HIGHS AND LOWS

As we said before, air masses begin to "spin" because of the earth's rotation. This and other changes form high-pressure and low-pressure air pockets. They generally move from southwest to northeast across the continent.

In a *low*, the low-pressure is at the center. The air blows in a spiral direction, opposite to a clock's hands. The inner air is warm and expands. The outer air is cool and pushes the warm air upward. In a *high*, conditions are just the opposite. The high pressure and cold air are in the center. The air blows outward in a clockwise direction. Look ahead at Fig. 102–1 in Chapter 14. You will see several highs and lows on the weather map.

WEATHER CHANGES CAUSED BY FRONTS		
Type	Speed	Weather Changes
Cold front	40–55 km/h	Temperature drops, pressure drops; dark clouds; heavy rain; lasts a few hours.
Warm front	25–35 km/h	Layered and icy clouds; slow, steady rain for a long time. Rain over an area of hundreds of kilometres.
Stationary front	Almost at rest	Weather same as in a warm front.
Occluded front	15–25 km/h	The warm air is pushed up by the 2 cold air masses and rain or snow follows.

HIGH AND LOW WEATHER
(Northern Hemisphere)

LOW (cyclone)	*At the Center:* Warming temperature; cloudy; rain; air moving upward in a counterclockwise motion.
HIGH (anti-cyclone)	*At the Center:* Cooling temperature; clearing skies; dry air moving downward in a clockwise motion.

HIGHS follow LOWS from west to east.

8. HOW IS THE WEATHER BORN?

It is now time to return to our *Target Question.* Our weather is born when air masses are formed.. After they are formed, they move and change. Their movements give birth to fronts and to highs and lows. The changes in temperature, wind, air pressure and moisture give us our changing weather.

YOU NOW KNOW

- When air masses meet, they form air mass fronts.
- The changes in the air at the fronts cause changes in weather.
- The nature and path of the fronts help us predict weather.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 13?

1. Air masses are bodies of air floating in the troposphere.
2. Barometers help us study air masses.
3. Front weather is different from weather in highs and lows.
4. Air masses form air mass fronts that form the weather.

II. In which paragraph do you find the answer?

1. In what directions do currents move in cyclones?

2. What causes air masses to spin and move?
3. How are warm fronts formed?
4. How wide an area do air masses cover?

III. Knowing What and Why

1. The temperature and humidity of an air mass is very much like the
   a. troposphere above it.
   b. atmosphere behind it.
   c. atmosphere to both sides of it.
   d. water and land below it.
2. The air masses which form over land are called
   a. maritime.
   b. tropical.
   c. continental.
   d. polar.
3. Knowing the source of an air mass tells us its
   a. temperature and direction.
   b. precipitation.
   c. pollution rate.
   d. age.
4. When air masses meet, they form
   a. mixed weather.
   b. cancelled forces.
   c. polar masses.
   d. fronts which move from west to east.

IV. Finish the story by choosing the word from the list below.

Weather is born in the (1). Here, we find floating (2) which are started in two places: over land, when they are called (3); over water, when they are called (4). In the U.S. and Canada cold fronts come from the north in (5) or from over the (6). Masses get their characteristics from their (7). Generally, a warm front is (8) than a cold front.

air masses
maritime
Canada
environment
Mexico
continental
smaller
Pacific Ocean
larger
troposphere

V. Choose the one word in the list of three that includes the other two.

Example: dime, coin, nickel. The answer is *coin,* because the dime and nickel are coins. Explain each answer

1. maritime tropical, continental polar, air mass ________________
2. front, warm, cold ______________
3. barometer, aneroid, mercurial __________
4. rain, snow, precipitation ________
5. cloud, nimbus, cirrus ____________

VI. Which two statements about *highs* and *lows* are incorrect? Explain why.

1. Movement of highs and lows is caused by the earth's rotation.
2. Highs and lows are exactly the same, except for pressure.
3. Highs and lows generally move across North America from southwest to northeast.
4. Highs and lows appear on a weather map.
5. Highs and lows are formed mostly in the mountains.

14

TARGET
What does a weather map show us?

Showing It on a Weather Map

1. STATISTICS AND WEATHER

Collections of facts and figures are called STATISTICS (stuh-TIS-tiks). Such figures are sometimes put on charts and graphs. Other figures are added and divided to obtain averages. For example, the average rainfall for January in New York City is 83 mm; the average temperature for New York City in January is 1°C. In San Juan, Puerto Rico, the average January rainfall is 103 mm. The average January temperature in Puerto Rico is 24°C.

Knowing baseball team batting averages helps us to predict the winning team. Knowing weather statistics helps us to predict the coming weather. Just as our baseball predictions sometimes come out wrong, so too our weather predictions are sometimes incorrect. But if we can use our statistics to make a large weather map, we may be able to forecast more correctly.

2. THE WEATHER STATION GOES TO WORK

The national weather service has many local weather stations. At each station the weathermen read their in-

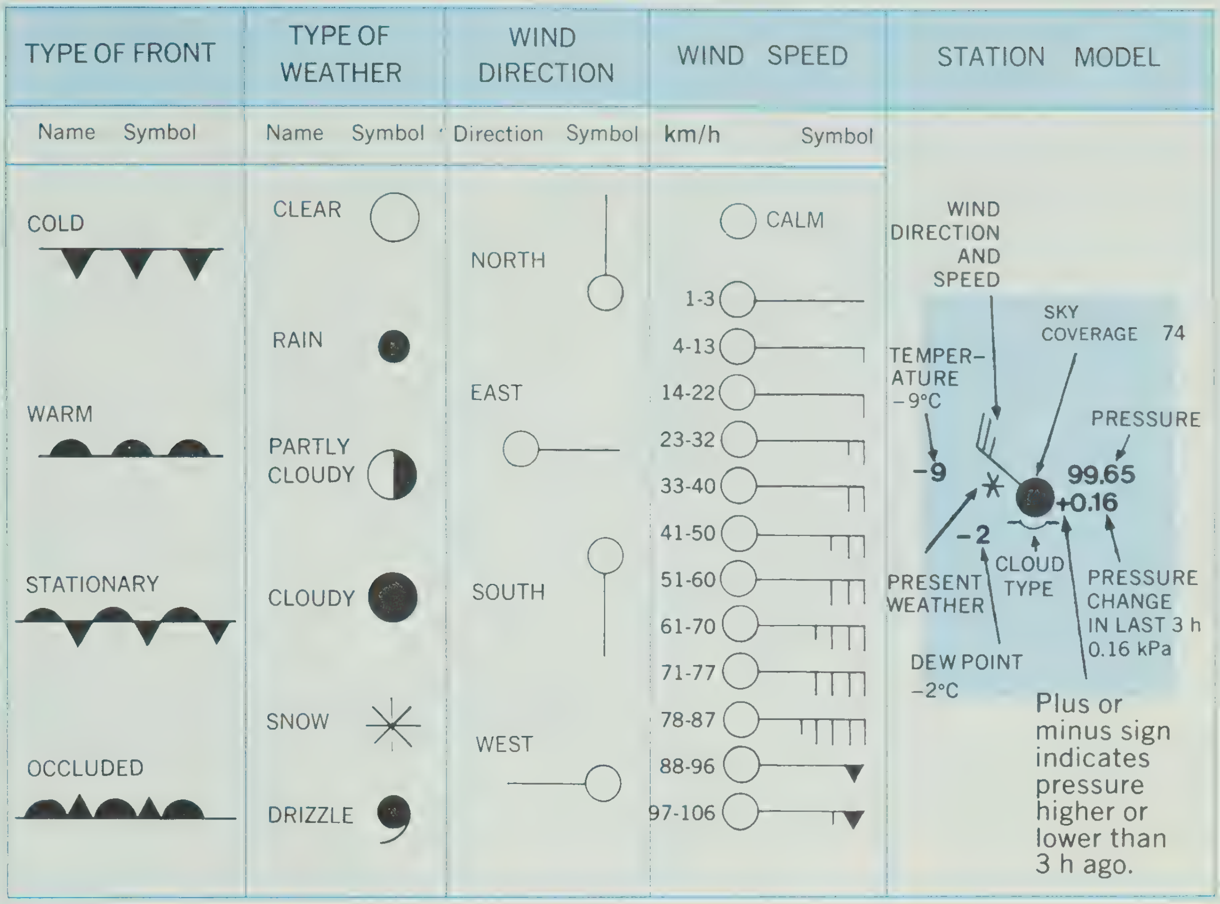


Fig. 101–1

The station model uses picture symbols.

struments and record the data. These weathermen use a system for telling about the weather in their part of the country. This information makes up the *station model*. Fig. 101–1 shows a station model. Notice that it uses picture symbols.

3. THE CENTRAL STATIONS GO TO WORK

After the local station has its data, it sends it to a central station by teletype, radio, telephone or telegraph. When the information comes in, it is drawn in on large maps. Each circle means one station. The station's figures are placed around its circle. Then more data is drawn in by the scientists. The whole map is then printed. When the local stations get the maps, they study them carefully. Then they make predictions for their local communities. Some people often blame the weather service for not being correct in their predictions. Did you know that over a long period of time the weather service is more than 80% correct? That is a very good record!

4. LET'S LOOK AT THE WEATHER MAP

Fig. 102–1 shows a typical weather map. This map shows only the weather for the United States and Canada. It was blank before the central station got to work on it. Let's look at it.

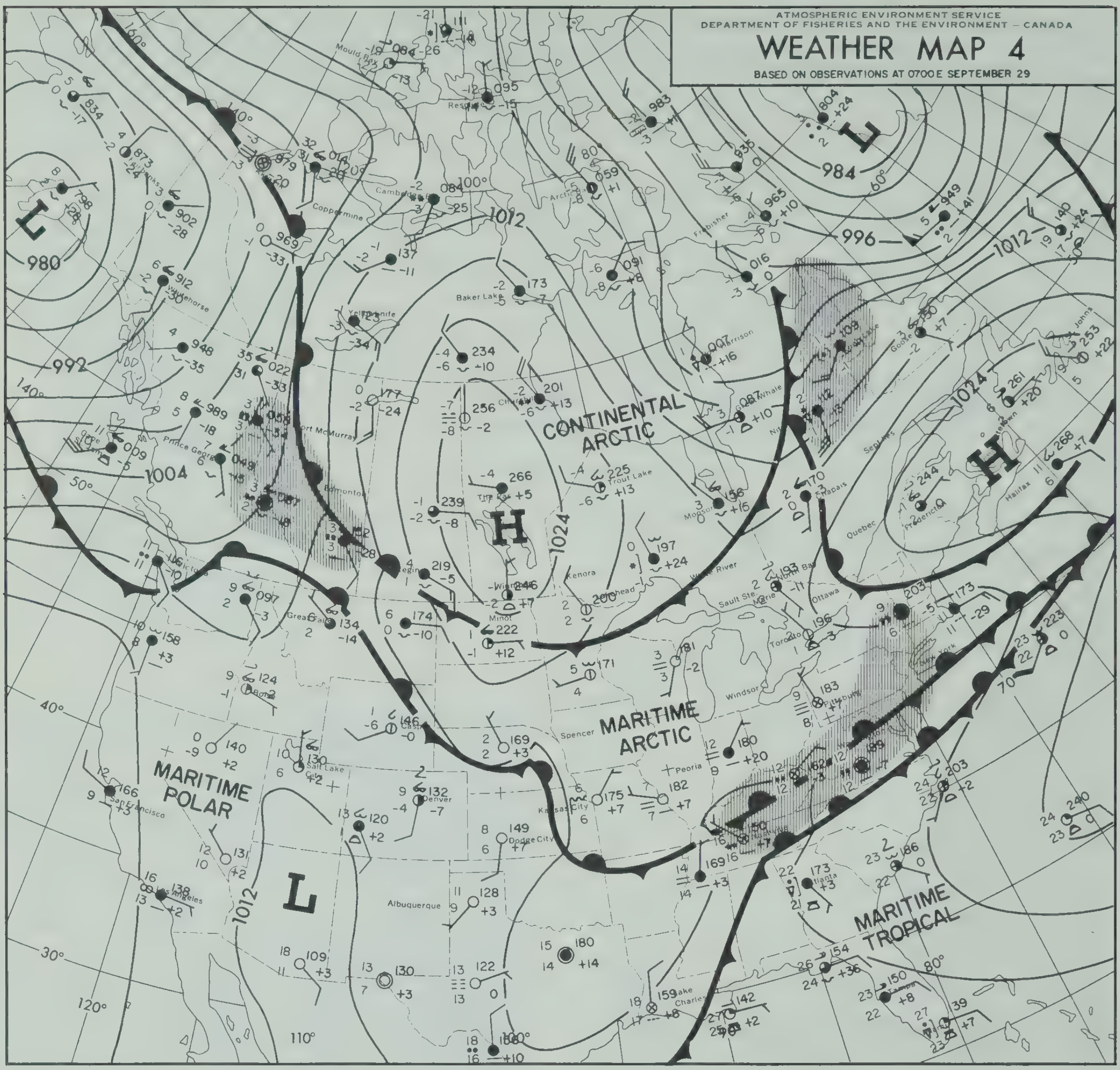


Fig. 102–1

What does this weather map show?

Notice the many circles on it. These are the major weather stations. Then there are many lines. The letters H (high) and L (low). There is a shaded portion around Nashville and around Edmonton. Shaded portions show precipitation (rain). There is a cold front in the west. Now let us explain what it all means.

LINES: The lines are called ISOBARS (EYE-so-bars). (*Iso* means equal; *bar* means pressure). Find the beginning of the line marked 1004 in the Pacific Ocean. Follow the line with your finger. It will take you up over part of north-western Canada and the Arctic Ocean. All places along this line have a barometer reading of 100.4 kPa. The third isobar in from this is marked at 99.2 kPa and the sixth is marked as 98.0 kPa. The pressure is getting lower. Therefore, in the center, an L meaning *low* is printed. Isobars surround highs and lows.

NUMBERS: Each number at a station tells you something about the weather. Study the simplified model on page 101. The temperature in Denver is 9°C. What is the temperature in Toronto?

SKY CONDITIONS: San Francisco is cloudy. What does Albuquerque show?

What does the map show for your area? Listen to the weather news on TV or radio and check your local paper. With the information you find construct a station model for your area.

5. HOW IS A WEATHER MAP USED TO PREDICT WEATHER?

The weather map shows movements of air masses, fronts, highs and lows. The low in the west will move northeast in a few days. By watching movements and knowing the usual path of air currents, we can predict fairly well for about five days. What would you predict for your area?

YOU NOW KNOW

- Weather data is collected into a station model.
- Central stations collect information from station models.
- Weather maps show weather conditions across the country.

6. SPECIAL JOBS OF THE WEATHER SERVICE

"Small craft warnings are out today along the entire eastern seaboard." So says the radio announcer! The national weather service performs many jobs for many people. In this case, they were warning boating people to watch out for storms. The chart shows you other services they perform. Can you suggest what each one does?

National Weather Service

Forecast and Warning Service
Aviation Weather Service
Agricultural Service
Fire-Weather Warning Service

Fig. 103–1

The national weather service supplies services that protect property and save lives. This man is sending photographs taken by a satellite to another branch of this service.

7. YOUR OWN WEATHER STATION

Can you be an amateur forecaster? Yes! You will need a few simple instruments: weather vane, thermometer, barometer and rain gauge. You will have to learn to recognize types of clouds. You will have to keep records of your observations. Over a long period of time, you will find that you are right much of the time. Of course, you can compare your predictions with those of the national weather service. Does your school have a Weather Watcher's Club? Ask your teacher. Perhaps you can start one!

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 14?

1. Fire prevention in forests uses weather data.
2. Weather stations collect weather data from different areas of the country.
3. Weather stations issue weather maps.
4. Weather stations issue storm warnings.

II. Explanation, please . . . answer in one or two sentences.

1. What is a station model?
2. What services, other than weather forecasting, does the weather service provide?
3. What are isobars?
4. What percentage of success does the weather service have in its forecasts? Why not 100%?

III. Knowing What and Why

1. A central weather station is needed because
    a. weather is everybody's business.
    b. it is a government service.
    c. weather conditions are combined from many areas.
    d. it's always been done this way.
2. High and low areas are surrounded by
    a. isobars.
    b. isotherms.
    c. warm fronts.
    d. small craft warning signs.
3. The direction of highs and lows is generally
    a. west to south.
    b. west to northeast.
    c. swirling all around.
    d. controlled by oceans.
4. Air masses are shown on weather maps as
    a. isobars.
    b. thermometer readings.
    c. front symbols.
    d. high altitude symbols.

IV. True or false? Explain your answer.

1. In the center of a high, the pressure is lower than at the edges of the high.
2. To predict weather, you really ought to study the maps for two or three days in a row.
3. A weather map for January 4, 1969 will be almost identical to the map of January 4, 1970 and January 4, 1971.
4. A low is generally weather which is wet and cloudy.
5. The national weather service is right 80 d a year, and wrong 20 times a year.

V. For Fun and Knowledge

1. Write to the national weather service for free booklets about their work.
2. Find out the location of the nearest weather station. Try to arrange a visit to see how it works.

VI. For the Science Reporters

1. Look back at old newspapers in your library. Write reports of some big storms.
2. Discuss with your English teacher the names of famous short stories that depend on the weather for their themes or stories.
3. Ask your English teacher to recommend poems that "paint pictures" about the weather.
4. Collect old "weather sayings." Discuss their truth or falseness.

15

TARGET
What do we know about the big storms?

The Freaks of Weather

1. END OF A BEAUTIFUL DAY

The beach party was a great success. The food was good. Everyone enjoyed the swimming and the bright, hot sun. Then it happened! Heavy black clouds appeared and covered the sun. The blankets were blown around; beach chairs were overturned. The shrill whistles of the lifeguards, as they ordered swimmers out of the water, could barely be heard above the thunder. Lightning streaked across the sky. The rain fell in giant streams. The crowd scattered.

2. SUMMER THUNDERSTORMS

The summer thunderstorm that broke up the beach party started with the strong heating of air near the earth's surface. This started strong convection currents that whirled upward. The warm air was pushed up,

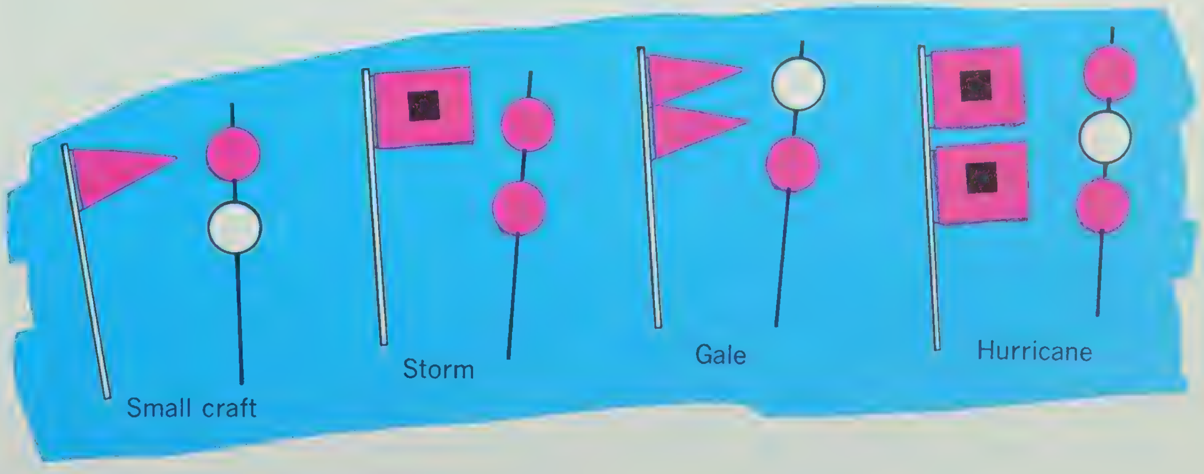


Fig. 105–1

These flags are storm warning signals.

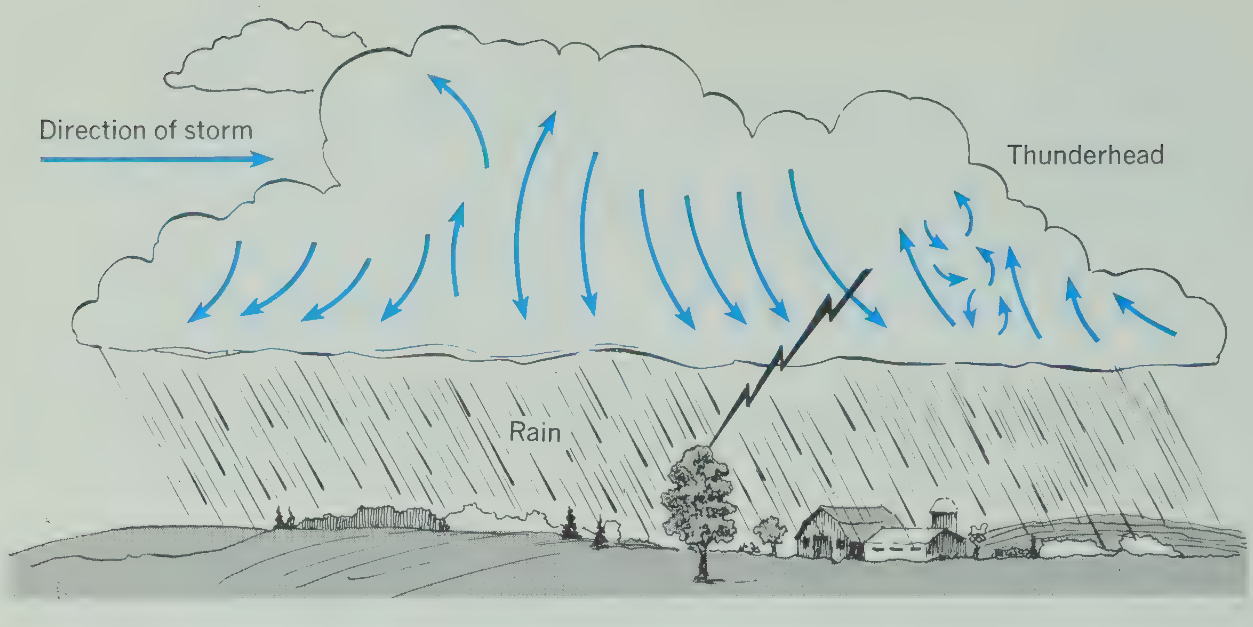


Fig. 106–1

A thunderstorm starts when moist air, rising in currents, condenses and drops rain. It is local and is over fast.

expanded and cooled. The cooling air reached the dew point above 0°C. The black clouds dumped the rain in huge amounts.

Meantime, the friction of falling raindrops and strong updrafts of air caused the upper part of the cloud to get a positive charge and the lower part of the cloud to get a negative charge. When this electricity discharged, streaks of lightning flashed across the sky. The lightning heated the air and caused it to expand suddenly to form an air wave. This was the thunder.

And yet, when you got home, the sidewalks were dry. Your mother looked at you strangely, since she saw no rain, no lightning and heard no thunder. Of course not. Summer thunderstorms are local, they cover only a narrow area. An hour or two after the storm, the beach was dry and sunny again. It was all over.

3. LOOKING BACK . . .

The *lows* we studied in Chapter 13 are really small storms, called CYCLONES (SY-klohnz). The center of a cyclone is a very low-pressure area and the air blows counterclockwise inwards and upwards. Cyclones bring rain. However, cyclones are really not violent storms in the northern hemisphere. Their rains are usually slow and steady. Their winds do not usually cause great damage. The path of cyclones is from west to northeast.

4. WATCH OUT FOR AMY! WATCH OUT FOR BLANCHE!

In 1953, the U.S. National Weather Service began the colorful practice of naming certain storms with female names. These names apply to HURRICANES (HUR-i-kaynz) in the Atlantic, Caribbean and the Gulf of Mexico. The hurricane season begins June 1

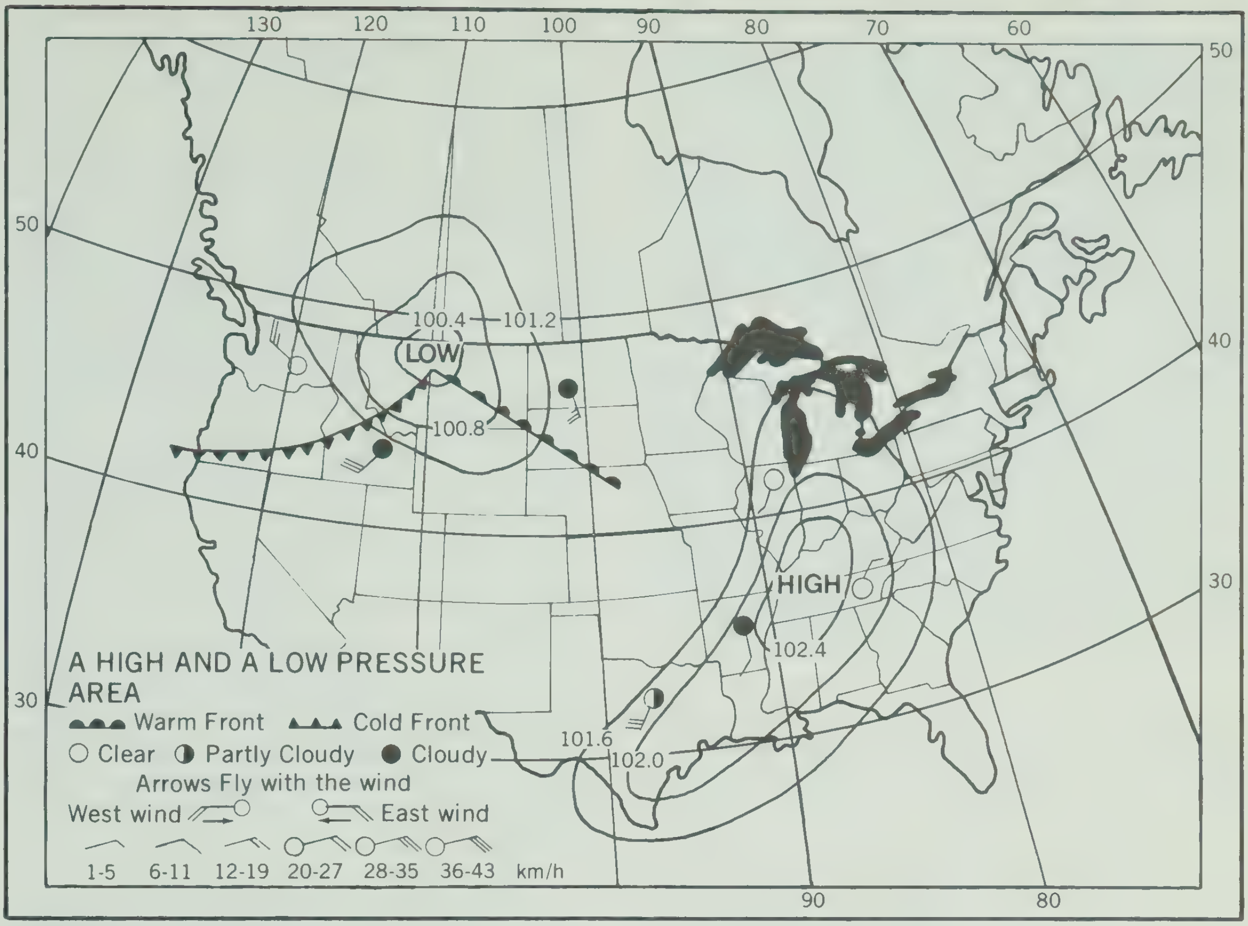


Fig. 107–1

The whole *low* (cyclone) moves along, carrying warmer air, with clouds and rain.

and ends November 30. Each year ten names are chosen in alphabetical order. For 1977, some of the names were Anita, Babe, Clara, Dorothy, Evelyn, and Frieda.

5. WHAT ARE HURRICANES?

First, you know that they are storms. Second, they are seasonal storms, usually coming in August and September. Barometer readings show very low pressure. As in cyclones, the air spins counterclockwise towards the center.

If you look at Fig. 108–1, you will see that U.S. hurricanes start near the West Indies, in the Caribbean Sea. That is why we say that a *hurricane is a tropical cyclone.* The prevailing winds blow the storm away from the equator. The arrows show that it moves north and turns east. It follows the eastern shores of the U.S. (the Atlantic seaboard) and then goes to sea.

Hurricanes are about 450 to 650 km wide. Hurricane wind speed is from 120 to 160 km/h. As they move, the heavy winds cause much damage to trees, houses, ships and livestock. The very heavy rains cause flooding and auto accidents. Early warnings by the national weather service are important, since they let people prepare for the coming storm.

An interesting thing about a hurricane is that it always has a calm cen-

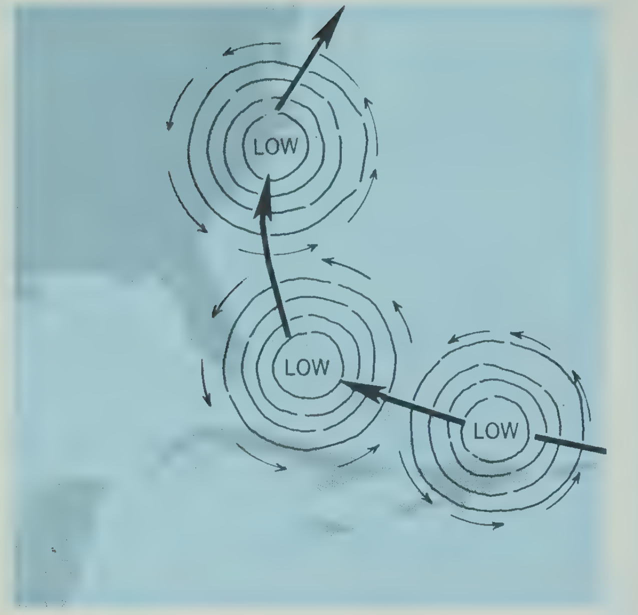


Fig. 108–1

Since we know the path of a hurricane, advance warnings can save property and lives.

ter called the *eye*. The eye is from 8 to 32 km wide. And, believe it or not, in the middle of this violent storm, it is calm, clear, without wind and without rain.

YOU NOW KNOW

- Thunderstorms can come in the summer and bring lightning and rain.
- Hurricanes are tropical cyclones that follow a known path, bringing heavy rain and winds.

6. TWISTERS CAN BE KILLERS!

Each year, people in Iowa, Kansas, Arkansas, Oklahoma, and a few other places in Central North America live in fear that they may be hit by a TORNADO (tor-NAY-do). Tornadoes are also called twisters. There are over 200 tornadoes each year; the twisters are most frequent in April, May, June and July.

When a tornado comes, it is a "killer-storm." It covers only a small area, from over fifty metres to over a kilometre. The wind, with a speed of about 480-800 km/h, circles to the inside low pressure. The air is forced upward in a draft which may reach 160 km/h. As the air spirals counterclockwise upward, it forms a dark funnel-shaped cloud. The clouds burst, releasing violent rain with thunder and lightning. Crops are destroyed; houses are shattered. Humans and even autos have been picked up by the funnel and thrown bodily downward.

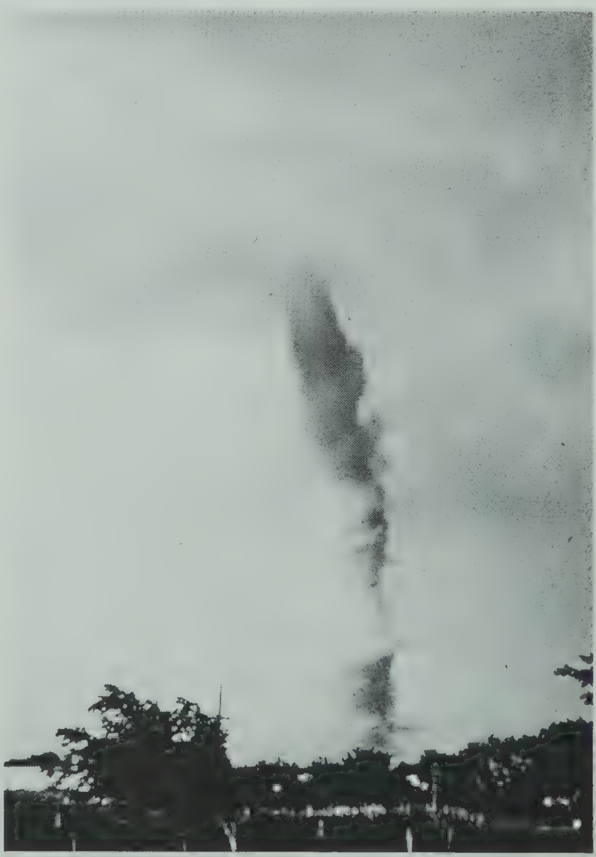


Fig. 108–2

Tornadoes have a narrow, powerful upward funnel. They cause great damage.

7. CAUGHT IN A BLIZZARD

The history and literature of America often talks of the *Blizzard of Eighty-Eight*. They are talking of the great snowstorm of 1888. Snow began to fall at midnight on March 11 and lasted until 3:00 p.m. March 14. The blizzard dumped 53 cm of very fine snow, very tightly packed. There were 400 deaths reported. The national weather service does not use the word *blizzard* unless the wind speed is at least 56 km/h. There have been other snowstorms and blizzards greater than the "eighty-eight." For example, a snowstorm in New York City on December 26-27, 1947, piled 68 cm of snow in Central Park. Blizzards take place in very cold temperature. In addition, they reduce visibility for planes, buses, cars and even pedestrians. Being caught in a blizzard is far from fun! It can be very dangerous.

8. CAN WE MAKE RAIN?

The American writer, Mark Twain, said, "Everyone talks about the weather, but nobody does anything about it." This may sound silly. But scientists are on the way to success in making rain and snow.

One successful method is to drop small particles of dry ice (solid carbon dioxide) from a plane into clouds. The cloud temperature is lowered, and condensation produces rain or snow. This was first done in 1946 in Massachusetts. The clouds were high up and so snow fell.

A few years later, scientists found that very small crystals of *silver iodide*, dropped into clouds, would cause clouds to condense. Four-engined planes drop hundreds of burning flares that give off millions of silver iodide crystals. This method, called *seeding*, can produce rain over narrow areas. The results are not always

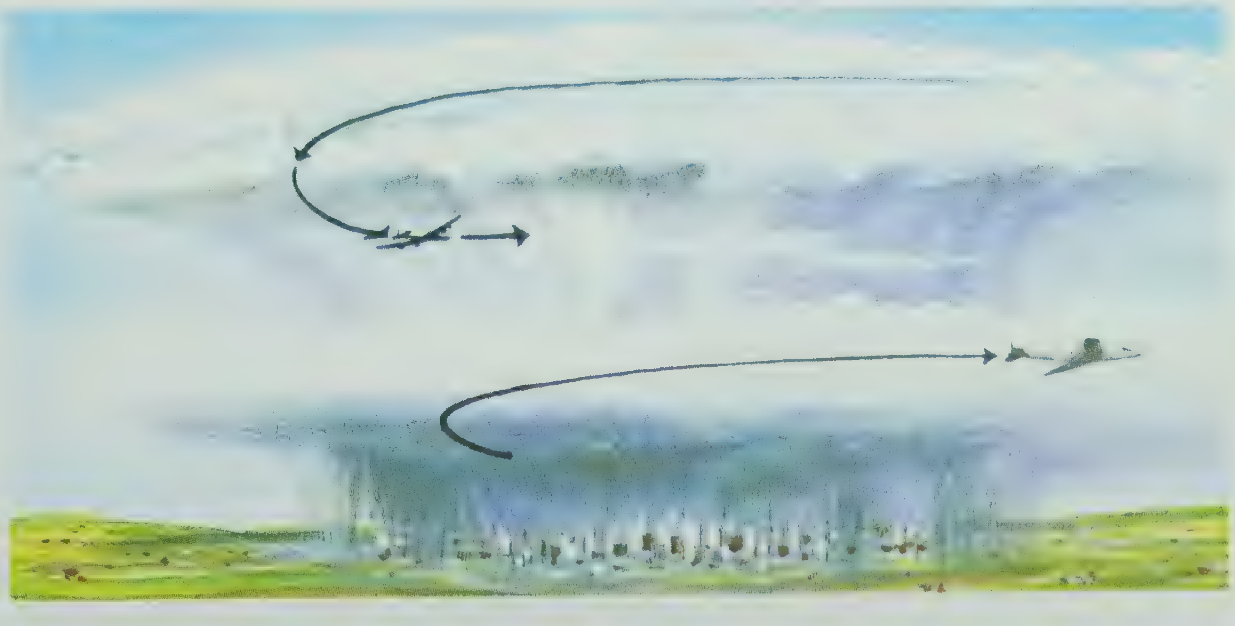


Fig. 109–1

Science is finding new and better ways to seed clouds. This produces rain or snow.

highly successful. Over desert areas, where dryness (drought) is worst, there are just not enough clouds to seed. In 1972, a seeding over Miami and the Everglades dropped 125 mm of rain after a severe dry spell. This research promises excellent results.

9. TO KILL A HURRICANE!

What's better than *predicting* a hurricane? Killing it!

For several years, NOAA has been conducting experiments to change and neutralize hurricanes. This is the famous PROJECT STORMFURY. It is more than a laboratory project—the laboratory is in the atmosphere!

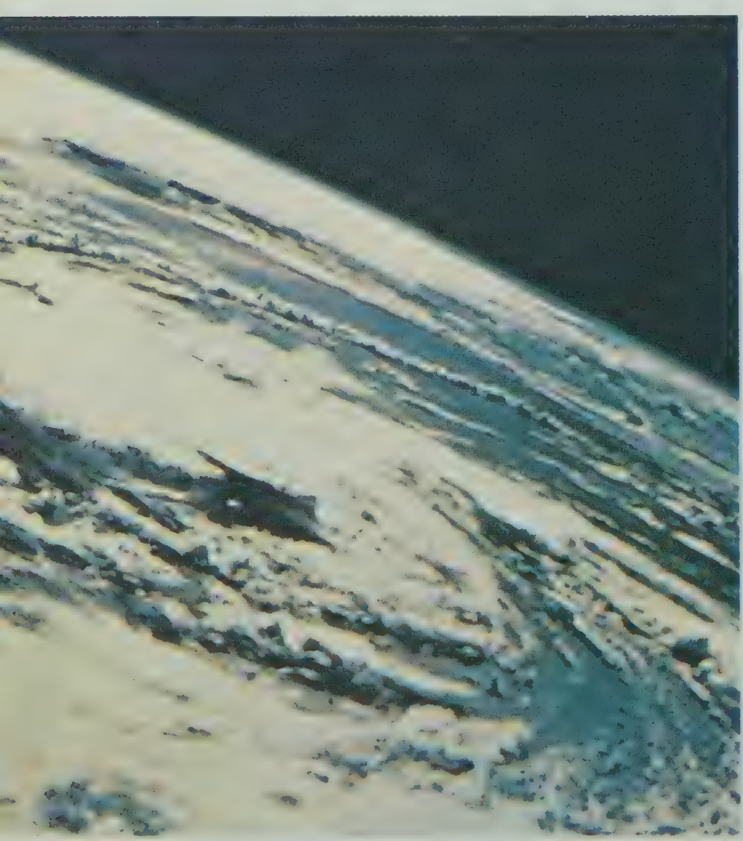


Fig. 110–1

This is a photograph of the eye of a hurricane. Seeding changes the clouds so that the winds near the eye are upset.

Stormfury uses the seeding method with silver iodide. Seeding is thought to change the clouds so that the winds near the eye are upset. The silver iodide releases heat from the cloud's water droplets and the pressure inside the hurricane is reduced. The idea is to spread out the winds and lose some of its fury. Several hurricanes have been treated this way with good results: Esther, 1961, Beulah, 1963, and Debbie, 1969.

10. SAFETY AGAINST STORMS

Since many storms can be predicted, we can prevent injury, death and destruction of property. When thunder clouds appear, swimmers and boaters should come in at once. Lightning can kill swimmers because salt water conducts electricity. When a storm strikes, take shelter, but not under trees. The sap of trees also conducts lightning. To avoid heart attacks, older people should avoid shoveling snow. People who walk during snowstorms should shield their faces from wind with a scarf, a newspaper or a face mask.

YOU NOW KNOW

- ► A tornado is a "twister" storm of high wind, powerful rain and great force.
- ► Blizzards are windy snowstorms with large drifts and low temperatures.
- ► Weather-making is the science of "seeding" clouds and the atmosphere to form condensation.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 15?

1. Hurricanes are heavy rainstorms.
2. Hurricanes are dangerous tropical cyclones which can be predicted.
3. Summer thunderstorms are dangerous.
4. Blizzards are heavy snowstorms which can be predicted.

II. In which paragraph do you find the answer?

1. Which type of storm has an "eye"?
2. What do we mean by seeding in weather?
3. What type of storm is funnel-shaped?
4. Why should you not swim during a thunderstorm?

III. Knowing What and Why

1. The basic idea in weather-making is to
   a. cause cyclones to move.
   b. change fronts.
   c. cause clouds to condense.
   d. change the direction of cyclones.
2. Which group of words does *not* describe hurricanes?
   a. seasonal, rain, low pressure
   b. seasonal, rain, high pressure
   c. seasonal, do not move very far
   d. every day of the year, never in the tropics
3. Most hurricanes in the U.S. start
   a. west of the Mississippi.
   b. southeast of Boston.
   c. in the Caribbean Sea.
   d. in the central Canadian Plains.
4. One successful weather-making project uses crystals of
   a. silver nitrate.
   b. silver chloride.
   c. silver iodide.
   d. a silver platinum alloy.

IV. Explain each of the following statements in one or two clear sentences.

1. Summer thunderstorms are the result of convection currents.
2. The National Weather Service spends much of its time in September studying hurricanes.
3. Boston fishermen worry about all hurricanes coming from Florida. Great Lakes fishermen worry little about them.

V. Understanding the Diagram

In Fig. 108–1:

1. In which direction is the storm moving?
2. Where did it start?
3. Where is the high pressure in each set of circles?
4. What are the connected circle lines called?
5. In which direction are the currents moving?
6. In which direction is the wind blowing?
7. The distance from Florida to the last position of the storm on the map (top of page) is 1 770 km. How long did the hurricane take to get there from Florida?

VI. For the Amateur Scientist

Set up a record page in your notebook for this year and next year. List the major hurricanes, blizzards, cyclones and rainstorms in your area by date. For each one give wind speed, temperature, pressure and amount of precipitation.

VII. For the Science Reporter

Read *National Geographic*, April 1972, pages 518-555, "We're Doing Something About The Weather." Prepare a report for your class.

16

TARGET
What makes different climates?

Weather from Place to Place

1. CLIMATE HERE . . . CLIMATE THERE . . .

"Weather changes from day to day:
The climate we have is here to stay."

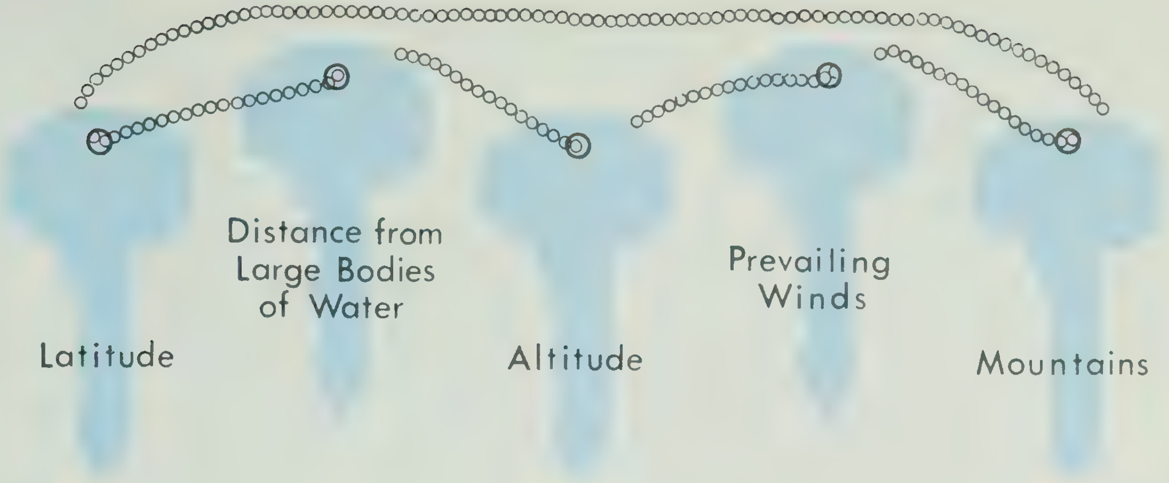
This little rhyme quickly tells the difference between weather and CLIMATE (KLY-mit). Climate is really weather over a long period of time. In Chapter 14, Paragraph 1, we spoke of *weather statistics*. These are numbers which we put together for tables, charts and graphs. From these figures, we get many important ideas about weather. Look at the table below.

SAMPLE WEATHER FIGURES

Average yearly temperature (add up daily temperatures; divide by 365)	25°C
Temperature range (lowest; highest)	−10°C - 32°C
Average rainfall (add up daily rainfall; divide by 365)	0.12 cm
Total rainfall for year (add rainfall)	42.5 cm
Number of hurricanes	3

2. THE CLIMATE MAKERS

Climate is really average weather. We therefore consider the same factors: temperature, moisture, winds, fronts, snowfall. As you saw in Paragraph 1, we consider these factors over long periods of time. What are the big climate-making keys? There are five chief keys.



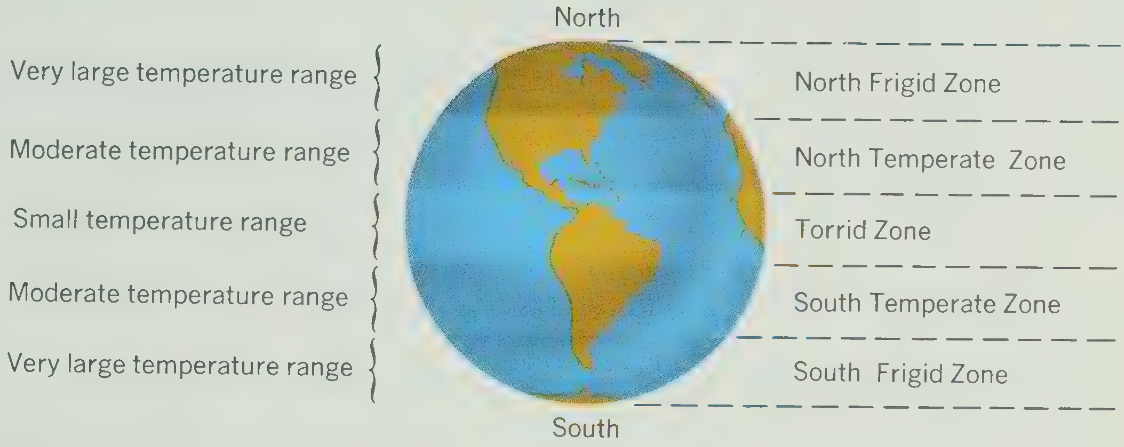


Fig. 113–1

3. LATITUDE AND SLANTING RAYS

Reread Paragraph 5 in Unit II, Chapter 6 (page 44). Now, look at Fig. 114–1 as you read the following. The lines of latitude are measured in degrees, north or south of the equator.

DO THIS RESEARCH

(1) Get an almanac (*World Almanac* or *New York Times Almanac*). Look up the figures for the blank spaces in the table below. Look at the map, Fig. 114–1, as you work.

Do not write in this book.

City and Province or State	Latitude	Average Temperature
Chicago, Illinois		
Miami, Florida		
New Orleans, Louisiana		
Vancouver, British Columbia		
Phoenix, Arizona		
Yellowknife, Northwest Territories		
San Francisco, California		
Mexico City, Mexico		
Canberra, Australia		

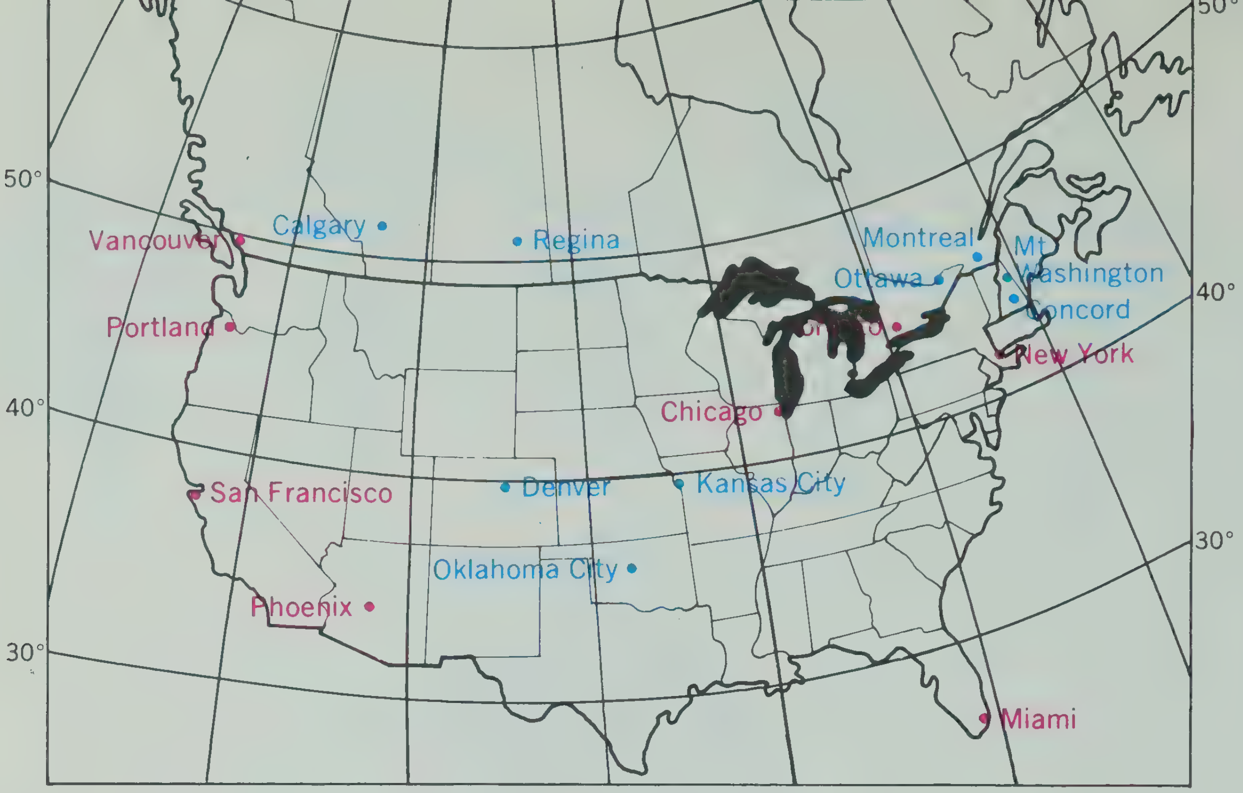


Fig. 114–1

The climate zones are based on latitude.

(2) We learn that, in general, the lower the latitude, the higher the average yearly temperature. The higher the latitude, the lower the average yearly temperature. The reason for this is that as you go to lower latitudes, closer to the equator, the earth gets more direct rays than slanted rays. Direct rays, as you remember, make more heat. More heat, higher temperature. Our earth can be divided into climate zones.

4. COMPARING TWO CITIES

Find Denver, Colorado on the map. Its altitude (height above sea level) is about 1600 m. Its average yearly temperature is about 10°C. Now find Kansas City, Missouri on the map. It is only 230 m high. This is only about one-seventh as high as Denver. Its average temperature is 14°C. Notice that the cities are almost at the same latitude (39°N Lat).

Do not write in this book.

City and Province or State	Altitude	Average Temperature
Denver, Colorado	1600 m	10°C.
Kansas City, Missouri	230 m	14°C
Calgary, Alberta		
Regina, Saskatchewan		
Concord, New Hampshire		
Mt. Washington, New Hampshire		

DO THIS RESEARCH

(1) Use an almanac to finish the table on page 114. Refer to the map, Fig. 114–1 as you work.

(2) This table shows again what you learned earlier. As we go to higher altitudes, air grows cooler. The drop in temperature is about 2 °C for each 300 m. The less dense air absorbs less heat.

YOU NOW KNOW

- Climate is average weather in a given place.
- In general, the lower latitudes (closer to equator) have warmer climates.
- In general, higher altitudes (height above sea level) have lower temperatures.

5. HEADING FOR THE SEACOAST

Planning a summer vacation? You might choose to go to the seacoast. What do we know about climate at the seacoast? You have already learned that land heats faster than water. (See Unit II, Chapter 6, Paragraph 4.) This is true for each day. It is also true for summer and winter.

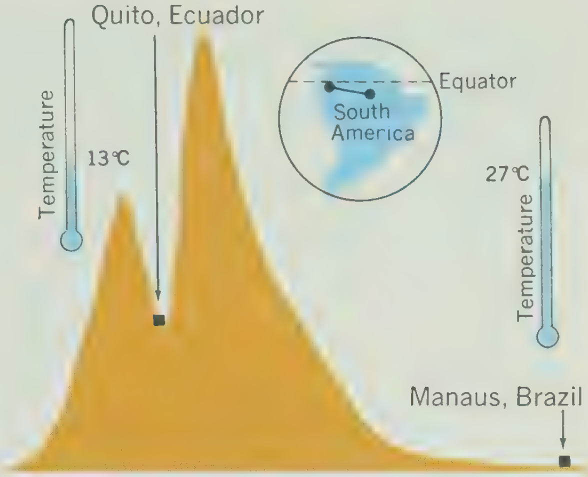


Fig. 115–1

Even though they are at the same latitude (near the equator), Quito is much colder than Manaus because of its higher altitude.

Let us see what the almanac tells us. We have chosen three pairs of cities. In each pair, the first city is at the seacoast. The second is inland. The two cities in each pair are located at about the same latitude. The table shows the highest average temperature (summer) and the lowest average temperature (winter). By subtracting low from high, we get the range of temperature.

TEMPERATURE IN COASTAL CITIES & INLAND CITIES

City and Province or State	Latitude	Highest Temp.	Lowest Temp.	Range
San Francisco, Calif.	37	18°C	9°C	9°C
Louisville, Ky.	38	26°C	2°C	24°C
Vancouver, B.C.	49	30°C	– 8°C	38°C
Winnipeg, Man.	50	32°C	–38°C	70°C
San Diego, Calif.	32	22°C	13°C	9°C
Dallas, Texas	32	29°C	8°C	21°C

From this table, you can see that nearness to an ocean keeps the temperature more even. Inland cities show more extremes in temperature. Nearness to water also means that the place may be feeling the results of warm ocean currents or cold ocean currents. We shall discuss ocean currents in Unit IV.

6. HOW DO WINDS CONTROL CLIMATE?

Look back at Fig. 95–1 which shows the path of the *prevailing winds* in North America. We see that they are the southwest westerlies: they blow from the southwest to the northeast. As these winds come in from the sea, they bring moisture. The west coast has cool summers and warm winters. The east coast has hot summers and cold winters.

7. MOUNTAINS AND DESERTS

Look at the west coast on a map of the U.S. The beautiful Sierra Nevada Mountains run north to south. On the western side of these mountains, we find much rain and lush fruit orchards. On the eastern side, there is the dry, crumbling "cactus country," the MOJAVE (mow-HA-vee) Desert; the Death Valley Desert and the deserts of Arizona and Utah.

The difference is easy to explain. As the prevailing westerlies hit the Sierra Nevada Mountains, the moist Pacific air moves up the slopes, cools and condenses to drop rain. The rain falls on the WINDWARD side. On the other side, the LEEWARD (LEE-word) side, the air moves down the mountains, compresses and heats up. It is a drying wind. Only a few plants, such as cactus, can live.

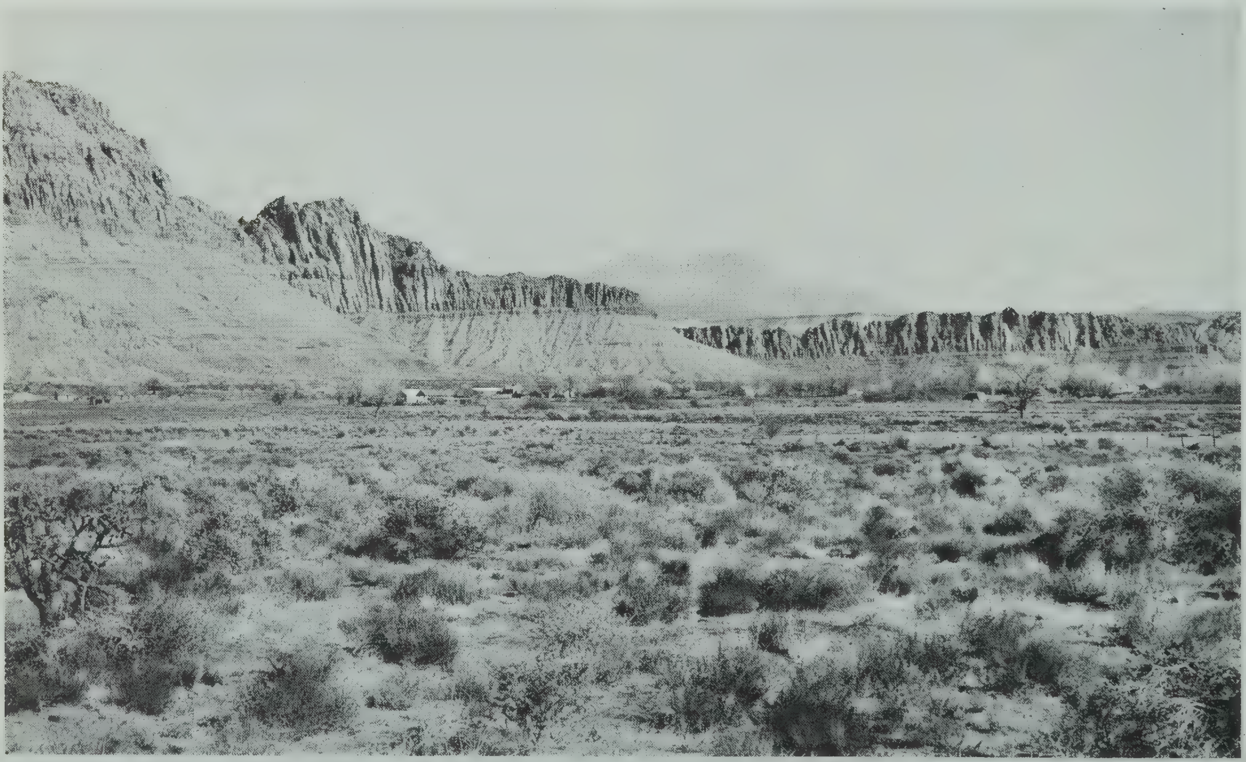


Fig. 116–1

Can you explain on which side of the mountain this desert is found?

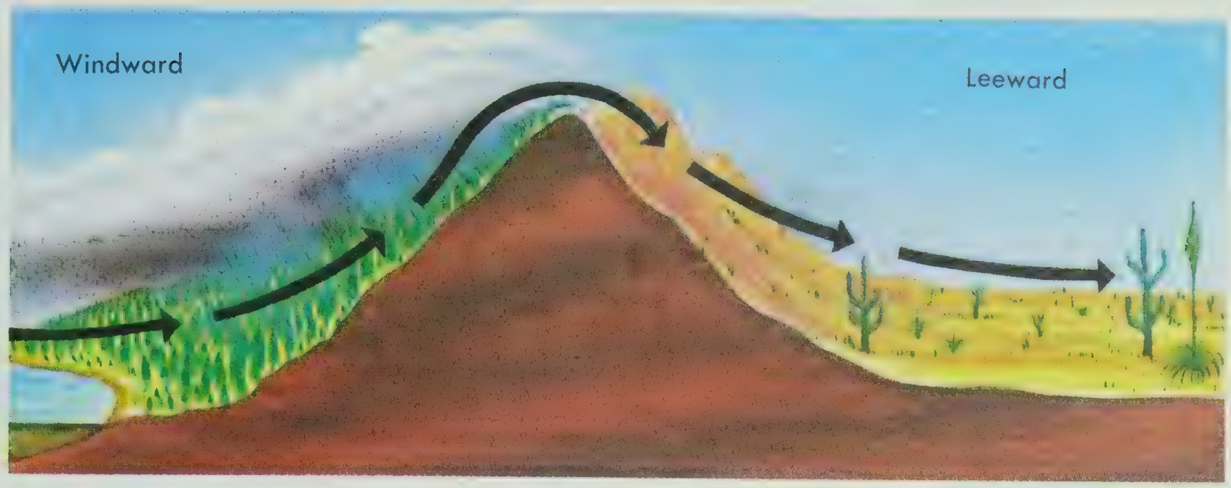


Fig. 117–1

Air loses moisture when it climbs over a mountain. On which side would you find the conditions shown in Fig. 116–1? Where is the cactus growing?

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 16?

1. Climate is the average weather in a given place.
2. Climate is formed by hurricanes, tornadoes, cyclones and blizzards.
3. Climate controls health and safety.
4. Climate is formed by altitude, latitude, winds, mountains and large bodies of water.

II. In which paragraph do you find the answer?

1. In what type of altitude do we find cooler weather?
2. Why are lower latitude countries warmer?
3. Why is there usually a desert on one side of a mountain?
4. Why is the temperature more even in San Francisco, California than in Louisville, Kentucky?

III. Knowing What and Why

1. Prevailing winds in the west bring
   - a. blizzardy weather.
   - b. cool summers and warm winters.
   - c. hurricanes
   - d. cyclones.
2. Windward sides of mountains have
   - a. cactuses and much moisture.
   - b. cactuses and desert.
   - c. moisture, flowers, shrubs and trees.
   - d. windstorms and dust storms.
3. The North Frigid Zone is generally
   - a. warm in the winter.
   - b. cold at all seasons.
   - c. temperate at all seasons.
   - d. like a desert.
4. Statistics are very important in studying climate because we must know
   - a. altitude.

b. wind speed.
c. ocean depths.
d. averages and range.

IV. Understanding the Ideas

At the top are the five factors that make climate. For each of the phrases on the bottom, state which factor is *most* related.

a. Latitude
b. Mountainside
c. Altitude
d. Distance from large bodies of water
e. Prevailing winds

1. 12 ° from the equator
2. Quite close to the Pacific Ocean
3. As high as Denver
4. Leeward
5. Northwest winds
6. Above the timber line
7. Slanted rays of the sun

V. For the Amateur Scientist

Study the climate of your own city in an almanac. List the following:

1. Average yearly rainfall
2. Average yearly temperature
3. Average temperature in February
4. Average temperature in July
5. Height above sea level
6. Number of hurricanes last year
7. Largest snowfall last year

VI. For the Artists

Copy Fig. 114–1 on a large poster board. Use colors. Label it carefully. Bring it to class.

VII. Brain Teasers

1. How many figures do you have to know to give a temperature range?
2. How do you get the average rainfall for twelve days?
3. What would be the approximate temperature on a mountain peak 1.83 km tall?

VIII. Understanding a Weather Report

From your local phone operator, get the number of the nearest national weather service. Telephone the number, listen carefully to the full report, take notes. (Perhaps your teacher can arrange to set up a tape recorder near your school phone. You can tape the report and play it back to your class.)

Repeat your calls for five successive days. On each day, compare the prediction with the actual weather.

1. List all of the weather factors the report gives you.
2. For each factor, tell what instruments were used.
3. If the actual weather is different from the prediction, how can you explain it?
4. For how many days is the prediction made?

Glossary: What Does It Mean?

air mass		A large body of air that has the same temperature and humidity.
anemometer	AN-uh-MOM-e-tur	An instrument that measures the speed of the wind.
anti-cyclone		A high-pressure area.
Aristotle		An ancient Greek philosopher and scientist who tried to predict the weather.
barograph	BAR-o-graf	An instrument that automatically records air pressure.
blizzard		A storm which brings cold, high winds and snow.
climate	KLY-mit	The average weather for an area.
cold front		Two air masses meet and the cold air pushes the warm air upward.
continental polar		A cold air mass which forms over cold land, usually near the poles.
continental tropical		A warm air mass which forms over warm land, usually near the tropics.
cyclone	SY-klohn	An area of low air pressure and circling winds.
forecast	FOR-kast	To tell what kind of weather is expected in the future.

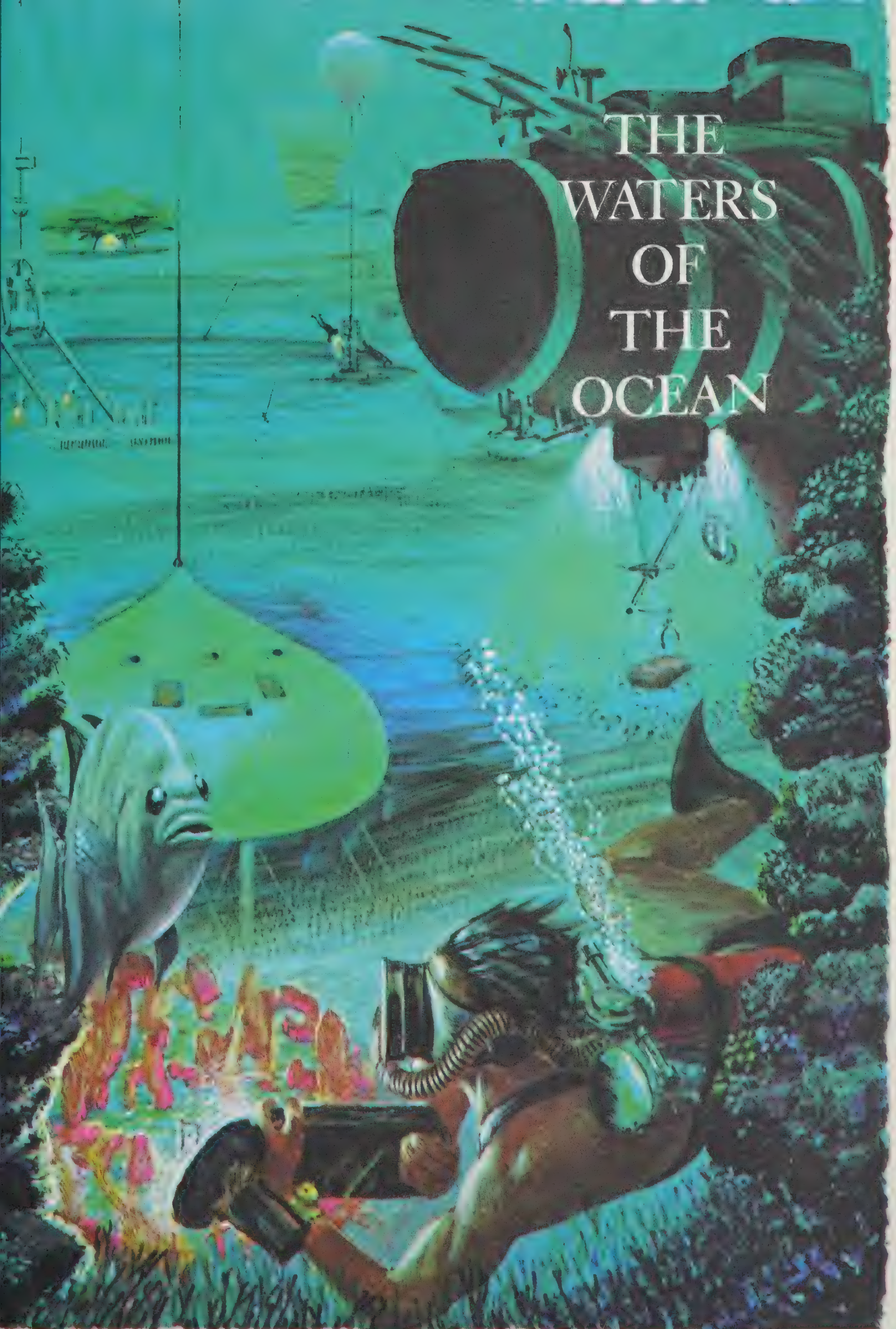
front		The boundary line between two air masses.
hurricane	HUR-i-kayn	A seasonal tropical storm usually forming over the Atlantic Ocean and having strong winds and low pressure.
hygrometer	hy-GROM-e-tur	An instrument used to measure the water vapor in the air.
isobars	EYE-so-bars	Lines on a weather map that connect two areas of the same air pressure.
leeward	LEE-word	The sheltered side of the mountain.
maritime polar		A cold, moist air mass that forms over oceans.
maritime tropical		A warm, moist air mass that forms over oceans.
meteorologist	mee-tee-oh-ROL-oh-jist	A person who studies the weather; the weatherman.
meteorology	mee-tee-oh-ROL-oh-jee	The science that studies the atmosphere and the weather.
millibar	MIL-i-bar	A unit of air pressure.
Mojave Desert	moh-HAH-vee	A desert in California.
National Oceanic and Atmospheric Administration (NOAA)		A branch of the U.S. Department of Commerce which studies oceans and atmosphere.
national weather service		Predicts and studies weather.
occluded front		Two advancing cold fronts that overtake a warm front. Rain usually follows.
prediction	pree-DIK-shun	A forecast or foretelling of what will probably happen in the future, especially with weather.
radar	RAY-dar	A device that sends out radio waves to locate and track storms or objects.
radiosonde		An instrument that records weather conditions in the atmosphere and sends them back to earth.

rain gauge	GAYJ	An instrument used for measuring the amount of rainfall in millimetres.
satellite	SAT-uh-lyt	A free-circling instrument in the atmosphere.
seeding		A method of producing rain by spreading silver iodide over clouds.
stationary front		The boundary between two air masses that remains in one place for a period of time.
statistics	stuh-TIS-tiks	The branch of math which gathers and classifies facts and numbers.
Stormfury		Project of NOAA to seed hurricanes to reduce their force.
thermograph	THERMO-graf	An instrument for continuously recording temperatures.
TIROS	TEE-rus	A weather satellite.
tornado	tor-NAY-do	A severe, small storm which starts over the land and has a whirling funnel-shaped cloud.
twister		Another name for a tornado.
warm front		Two air masses meet and the warm air pushes up and over the cold air.
weather		The condition of the atmosphere with regard to heat, humidity, clouds and precipitation.
weather station		A place where weather information is collected.
windward		The unprotected side of the mountain. The winds hit here first.

UNIT IV

The scuba diver (bottom) is an early discoverer of the wonders of the ocean. Many types of fish and plants are present. We are now exploring the oceans in great detail. The Sealab (upper right) is owned by the United States Navy. It has spent many months exploring under the sea. Notice the bathysphere (center), and the other experiments set up on the ocean floor.

THE WATERS OF THE OCEAN



UNIT IV

The Waters of the Ocean

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17

TARGET
How do we study the waters of the oceans?

The Earth's Waters

1. TWENTY THOUSAND LEAGUES UNDER THE SEA

Do you recognize the title? It is the title of a fascinating book of science fiction. This book was written shortly after our Civil War (1868), by *Jules Verne*. It is the story of the imaginary Captain Nemo and his fearless crew. They travelled in an imaginary boat called the *Nautilus* which had the power to explore the bottoms of the oceans! It was supposed to be able to travel a distance of 20 000 leagues while below the ocean's surface. A league is about 5 km. So, 20 000 lea-

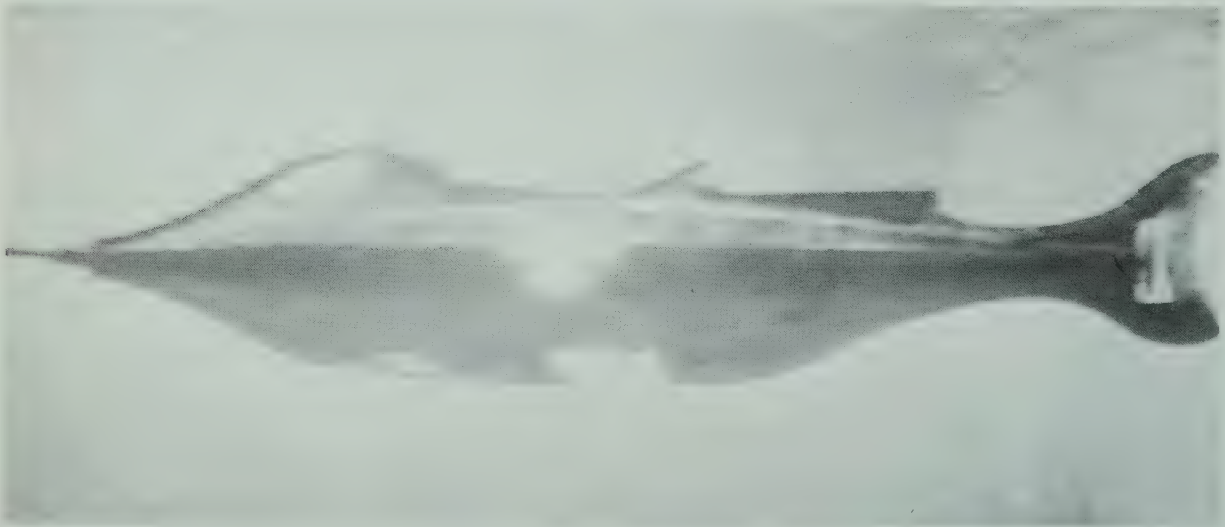


Fig. 126–1

This picture is of the *Nautilus* from Walt Disney's "Twenty Thousand Leagues Under the Sea." Jules Verne imagined the first submarine to look like this many years before submarines were developed.

gues is (20 000 × 5 km =) 100 000 km.

Today, it is not news to hear of ships below the ocean surface. Submarines are well known. But many of the things they see at the ocean's bottom are as exciting as the imaginary things that Jules Verne wrote about. No wonder the U.S. Navy called its first atomic submarine the *Nautilus!*

2. THE ROMANCE OF THE SEA

From the earliest days, man was fascinated by the seas and oceans. NAVIGATORS (NAV-i-gay-terz) sailed the seas and explored new worlds. GEOGRAPHERS (jee-OG-ruh-ferz) drew maps to show the oceans and these new worlds. A new, growing science is called OCEANOGRAPHY (O-shun-OG-ruh-fee). As you will see, oceanographers use their knowledge of biology, chemistry, physics and geology to study the oceans.

3. THE OCEANS WE KNOW

We learned earlier that the earth is about six billion years old. Shortly after the earth was formed, it shrank to form BASINS (BAY-suns) which filled with water. As time passed, the oceans became deeper and the water became salty.

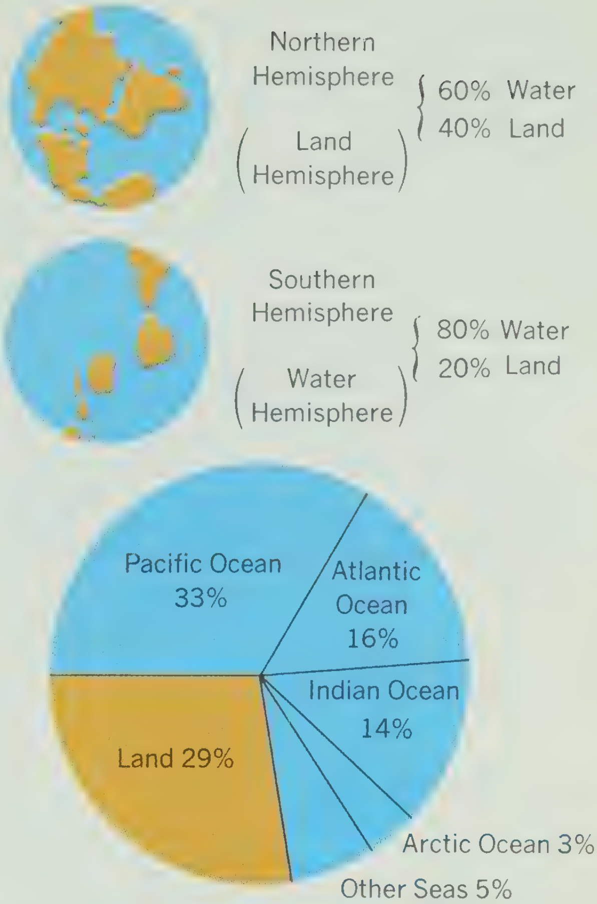


Fig. 127–1

Most of the land is in the northern hemisphere; most of the water is in the southern hemisphere.

The hydrosphere covers almost three-fourths of the earth (71%) to form 4 oceans and 21 seas. All oceans

OCEANS OF THE WORLD

Ocean	Millions of Square Kilometres	Width	Average Depth
Pacific	166	16 000 km	4300 m
Atlantic	83	5 800 km	3900 m
Indian	73	9 700 km	3960 m
Arctic	13	4 800 km	1220 m

Note: Most map makers do not use the term Antarctic Ocean. It is simply the southern part of the Pacific, Atlantic and Indian Oceans.

are connected. The land forms (continents and islands) are in the oceans. If you look at Fig. 127–1, you will see that most of the land is in the northern hemisphere. Most of the water is in the southern hemisphere. The northern hemisphere is 60% water; the southern hemisphere is 80% water.

YOU NOW KNOW

- Oceanography studies the chemistry, physics, biology and geology of oceans.
- The hydrosphere (water) covers 71% of our earth and forms 4 major oceans.

4. EXPLORING THE OCEAN

How do we start getting answers to questions about the oceans? The first way, of course, is to look at the ocean. We can see its waves and its motions. Sailors who went to sea could study the oceans far out from land. Airplanes and balloons can study the oceans from aloft. The most challenging problem was how to go below the sea.

To know about the sea, we must also study its water and its products in the laboratory. This means collecting samples of water. It means scooping up sediment from the bottom. It means collecting living things. To study the physical characteristics of the ocean, we must find some way to use scientific instruments in the ocean.

5. SAILING WITH AN R.V.

Fig. 128–1

The *H.M.S. Challenger* was the first ship used for an ocean-studying expedition.

"R.V.? What's that?" you ask. R.V. stands for *research vessel* or *research vehicle.* It is a special ship used for scientific research by oceanographers. R.V.'s float on the surface like other ships, but carry special oceanographer's instruments.

The first great ocean-studying expedition was made by the English

TO STUDY OCEANOGRAPHY

Use scientific instruments in the ocean.

Go below the surface of the ocean.

Pick up samples of water, materials and life in the ocean.

vessel *H.M.S. Challenger* in 1872. She stayed away for three and one half years and sailed 113 000 km. The boat would anchor frequently; instruments would be lowered to measure depth, temperature and currents. Sediment was scooped up. Almost 5 000 species of plants and animals never known before were collected. The science of oceanography was born! Vessels like the Atlantis II (Fig. 129–1) carry the finest instruments and have small laboratories on board.

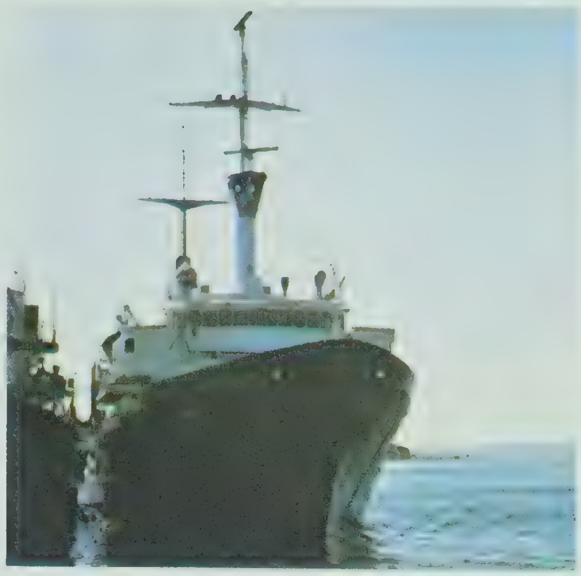


Fig. 129–1

The Atlantis II is an oceanographic research vessel. Scientists aboard this ship are unlocking the secrets of the sea.

6. DIVING BELOW THE OCEAN

In the early days, oceanographers depended on pearl divers to go below the sea. Now divers wear heavy rubber suits. A long hose connects them to an air pump on the shore or on the boat. Of course, they cannot go very far, and there is the danger of breaking the air hose, which means death.

Modern SCUBA (SKOO-bah) divers can stay underwater a long time because they carry tanks of oxygen with them. The letters in scuba stand for *Self-Contained Underwater Breathing Apparatus.* Even with these tanks of oxygen, and with more free movement, divers cannot stay down too long. At about 55 m below water, the body relaxes completely and the divers can no longer work.

7. SAILING WITH A U.R.V.

"What's a U.R.V.?" Of course! It's an *underwater research vessel* (vehicle). In 1930 the world was amazed to hear that Dr. William Beebe had gone more than 900 m (almost 1 km) down into the Atlantic Ocean. He was lowered in his BATHYSPHERE (BATH-i-sfeer), a huge steel ball with heavy windows. The bathysphere was tied to a ship by cables. Air hoses supplied air. Telephone lines gave them communication. But this was only the beginning.

The U.S. Navy is proud of its *Trieste II* which is called a BATHYSCAPHE BATH-i-skayf). The steel ball, the sphere, hangs from a very large float filled with gasoline. Gasoline, you may remember, has a lower density than sea water. It gives the ship more buoyancy. The bathyscaphe sinks and surfaces just like the submarine you studied in your physics work. Underwater, it moves by use of propellers. In 1960, JACQUES PICCARD (pee-KAR) lowered the Trieste to the bottom of the Pacific Ocean – 10 900 m.

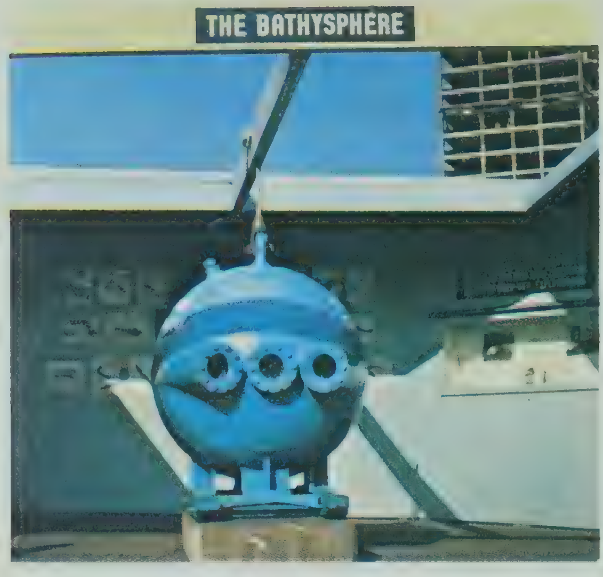


Fig. 130–1

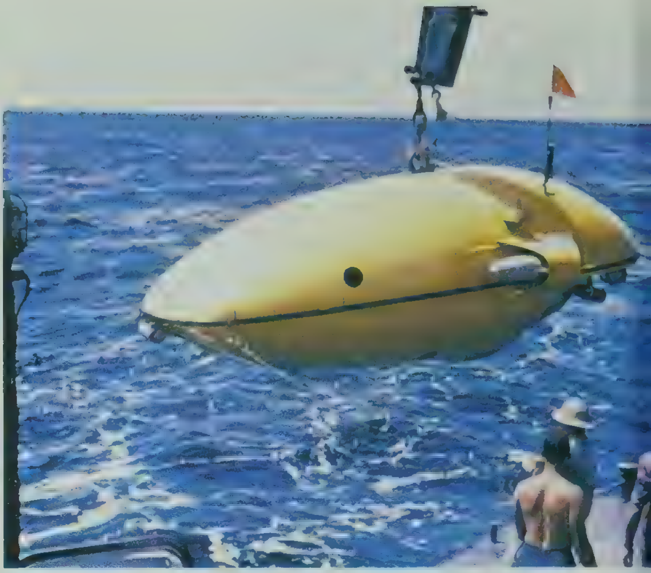


Fig. 130–2

Both of these vessels are used to explore the ocean. The bathysphere on the left stays in one place while the U.R.V. at the right is free to move about.

8. ON THE BOTTOM OF THE OCEAN

Now this sounds like real "magic." But it's true. The U.S. Navy has a new ship called *Sealab III*. It is just what its name says, a sea laboratory. In 1965, Navy AQUANAUTS (AKWA-nots) stayed 62 m below the surface of the Pacific Ocean for 45 d. On board, in command, was Commander M. Scott Carpenter, the world's only astronaut and aquanaut. Recently six French aquanauts spent six days at the bottom of the Mediterranean. They were under the command of the famous Captain COUSTEAU (koos-TOE) and lived 100 m below sea level.

YOU NOW KNOW

- At one time oceanography used only diving.
- Research vessels stay afloat but send down instruments and pick up samples.
- Underwater research vessels go below the surface of the ocean, even to the bottom.

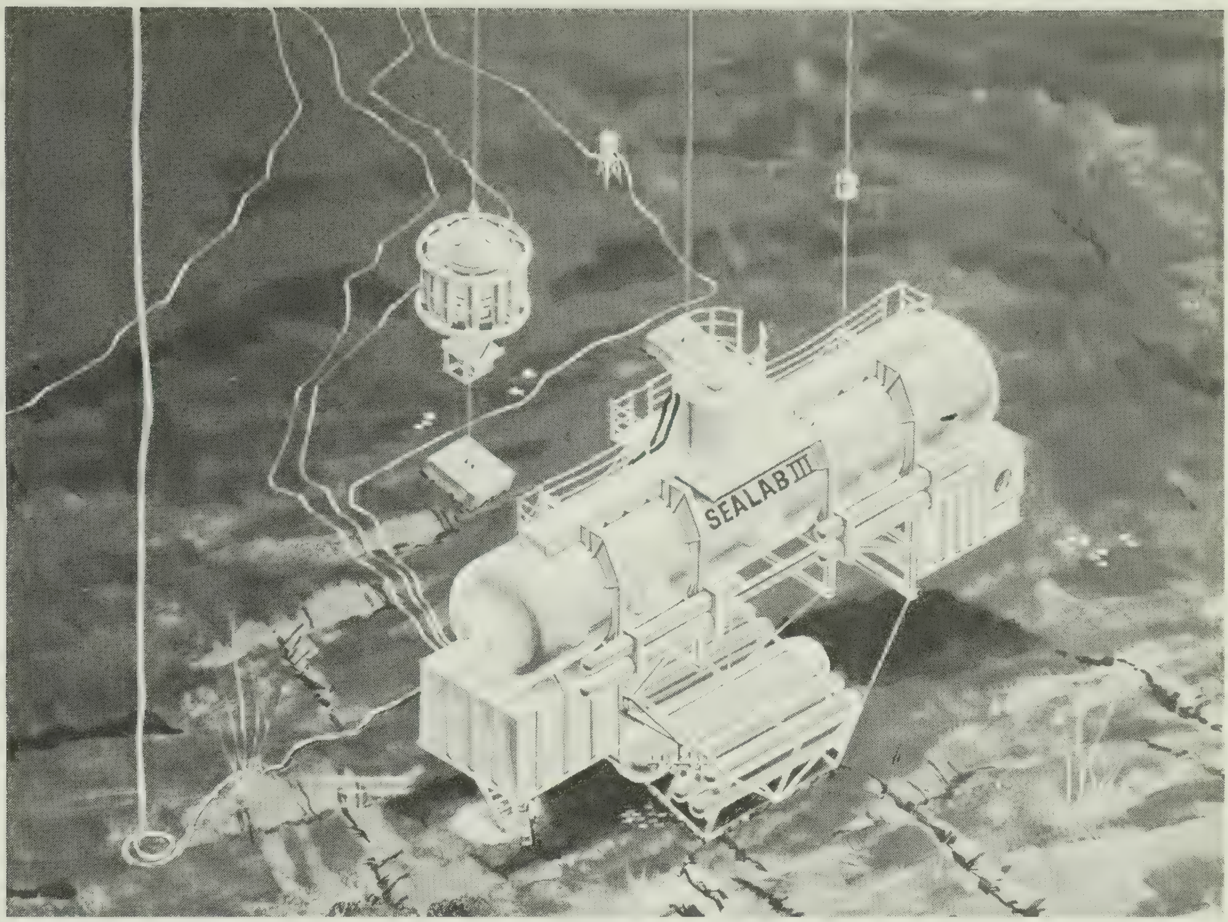
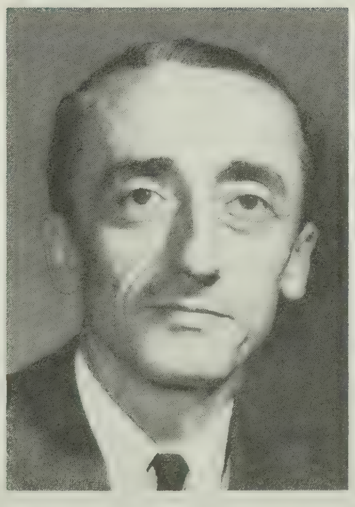


Fig. 131–1

The Sealab III has enabled men to live under the sea for short periods of time.

PROFILE OF A GREAT SCIENTIST

Jacques Cousteau (1910-).



Jacques Yves Cousteau, born in France, served briefly in the French Navy. He became an expert in "skin" diving, which is diving without a diving suit. During World War II, Cousteau fought the Nazis as a Commando, searching out submarines and mines.

In 1943 Cousteau developed the Aqua-Lung, a portable breathing device which made it possible for skin divers to go as deep as 90 m below the ocean's surface. Cousteau also developed the techniques for taking underwater motion pictures.

In 1960 Cousteau led a series of underwater expeditions called *Conshelf*, which showed that people can live underwater.

Cousteau has written many books about ocean life (*The Living Sea; The Silent World*), and has produced popular TV programs.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 17?

1. Navigators were the first to study oceans.
2. Oceanography is the science of the hydrosphere.
3. There are four major oceans.
4. Oceanography uses special vessels for research.

II. Explanation, please . . . answer in one or two sentences.

1. How can oceanography be studied in a laboratory?
2. How long have men been able to stay at the bottom of an ocean?
3. Which part of the earth has the most water on its surface?
4. Are the oceans connected?

III. Knowing What and Why

1. Oceanography studies a combination of
   a. biology and chemistry.
   b. chemistry and geology.
   c. geology, chemistry, biology and physics.
   d. geology and physics.
2. The Challenger is
   a. the popular name of a hero of the oceans.
   b. a group of ocean depths.
   c. an ocean-studying ship.
   d. a space capsule that floats on the ocean.
3. A sample of water from the bottom of the ocean might be studied
   a. to learn the ocean's depth.
   b. to estimate ocean temperature.
   c. to see the salt content.
   d. to check barometric pressure.
4. Scuba divers differ from the older pearl divers in that
   a. scuba divers are educated scientists.
   b. scuba diving is not dangerous.
   c. pearl divers did not have a supply of oxygen.
   d. scuba diving is done mostly in frozen waters.

IV. True or false? Explain your answer.

1. Most of the water is in the southern hemisphere.
2. A bathysphere is no different from a bathyscaphe.
3. A knowledge of geography is not important in oceanography.

V. Understanding Facts and Figures

Look at the chart on page 127.

1. Which ocean has the second largest area?
2. Which ocean is the third deepest?
3. Is it correct to say that the Pacific Ocean is almost as big as the other three oceans put together? Explain.
4. What is the *total* area of the four oceans?

VI. Who's Who in Oceanography

Write *one* or *two* sentences to show you know the contribution of:

1. Jacques Piccard
2. M. Scott Carpenter
3. Jules Verne
4. Jacques Cousteau

VII. Give the Full Name

1. SCUBA ____________
2. R.V. ____________
3. U.R.V. ____________

18

TARGET
What do we know about ocean water?

The Nature of Ocean Water

1. HOW DID THE OCEANS BECOME SALTY?

The ocean has been called the world's biggest salt solution. Scientists believe that when ocean water was first formed it was fresh, not salty. As the rivers on land flowed over the land and rocks, mineral salts were dissolved out and brought to sea. This theory is strengthened by the fact that the seas have been getting saltier and at a steady rate. As a matter of fact, you may remember that the SALINITY (sa-LIN-i-tee) or saltiness of the sea is used to estimate the age of the earth.

When you studied solutions you learned that the solutes do not separate from the solution. However, the water of the ocean does evaporate and makes the solution more concentrated. Evaporation is speeded up by heat and by wind. Just as you would expect, the Mediterranean Sea is saltier than the ocean because the westerly winds keep whipping the water to speed evaporation. Also, as you would expect, the ocean water near the poles is less salty than the rest of the ocean because ice and snow contain less salt. When ice and snow melt in the ocean, they dilute the solution and it is less salty.

The Great Salt Lake in Utah and the Dead Sea in Israel are located in areas of great heat. Rapid evaporation has made these two bodies of water the saltiest in the world.

2. WHAT CHEMICALS ARE DISSOLVED IN SEAWATER?

We saw above that the salinity of the sea is different from place to place. Careful tests show that the *average* salinity is 3.5%. This means that in a sample of seawater of 100 g, 3.5 g are solid salts and 96.5 g are water (H_2O). A sample from the Dead Sea would

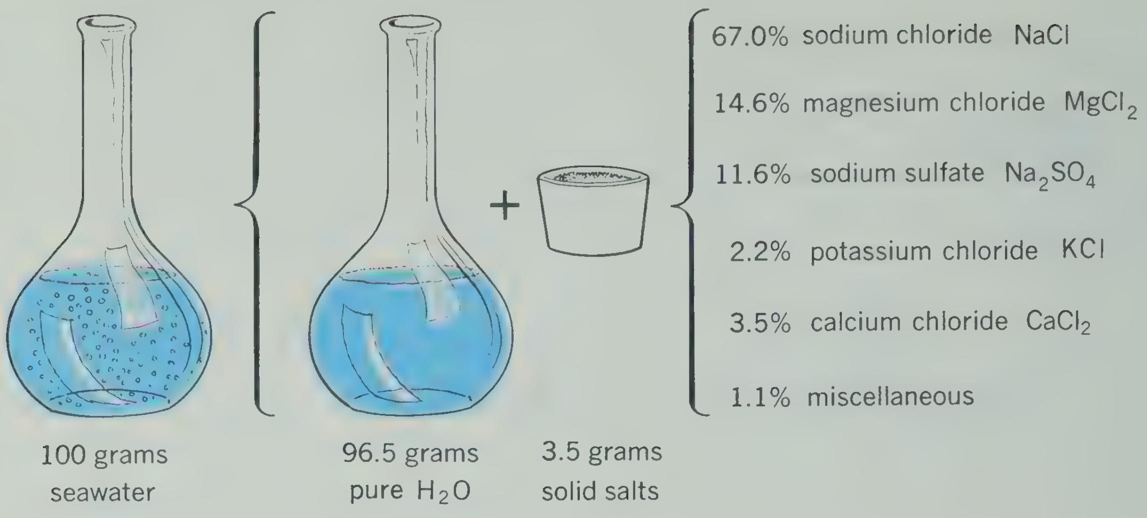

+
67.0% sodium chloride NaCl
14.6% magnesium chloride $MgCl_2$
11.6% sodium sulfate Na_2SO_4
2.2% potassium chloride KCl
3.5% calcium chloride $CaCl_2$
1.1% miscellaneous
100 grams seawater
96.5 grams pure H_2O
3.5 grams solid salts

Fig. 134–1

contain about 24 g of salt in 100 g of water. The chart above shows the average composition. Of course, the greatest amount is sodium chloride, table salt.

When seawater stands at room temperature, bubbles of gas appear. Oxygen dissolved in seawater is used by sea animals for respiration. Carbon dioxide is used by green sea plants for photosynthesis.

DO AND DISCOVER

Investigation 13: How can we test for chemicals in seawater?

1. Moisten solid sodium chloride with a drop of hydrochloric acid. Pick up some of the moistened crystals on a nichrome wire loop. Hold the loop in the Bunsen flame. A yellow color will appear.
2. Repeat with calcium chloride (orange-red) and potassium chloride (violet).
3. If you can obtain a sample of seawater, repeat this experiment to see which chemicals are present.

YOU NOW KNOW

- ► The ocean gets its salts from the minerals of the land, washed down by rivers.
- ► Seawater has an average salinity of 3.5 parts salt per 100 parts of water.
- ► The salts of the sea have been studied and are well known.

3. SCOOPING UP THE BOTTOM

Special shovels called DREDGES (DREH-juhz) and special tubes called CORERS (KOR-erz) are used to bring up samples of the sediment from the ocean bottom. And what a story it tells!

As you learned before, the heavier gravel and sand washed down by rivers settle near the shore. The thinner particles settle in the deep sea to form *ooze*. Ooze is formed from the dust of volcanoes. It has a reddish

Fig. 135–1

How do these tools help the oceanographer study the sediments of the sea?

color because of iron compounds. If you examine ooze under a microscope, you can also find deposits of calcium from the skeletons of microscopic creatures called DIATOMS (DY-a-tomz). Also, at the bottom of the ocean, there are clumps of manganese and cobalt. These NODULES (NOD-youlz), as we shall see later, are extremely valuable.

4. OCEAN WATER TEMPERATURES

You know from your experience that a dip in the ocean cools you off. But remember, you are very close to shore. How cold is it far out at sea? How cold is it 3 km down under the surface of the sea? As you would expect, there are special thermometers that have been lowered to take ocean temperatures. The BATHYTHERMOGRAPH (BATH-i-THERMO-graf) takes and records the temperature.

What do we know about ocean temperatures? In the first place, water at the equator is much warmer than at the polar regions because the equator receives direct rays of the sun. As you will see later, when you study ocean currents, there are warm currents and cold currents which keep changing the water temperature. Finally, you must remember that the sun's rays can only pass through a short distance of the water. The deeper the water, the colder it gets.

SAMPLE TEMPERATURES OF THE OCEAN

Equator and Tropics	30°C
North and South Poles	−2°C
Red Sea	32°C
Indian Ocean	27°C
3200 m below surface, down to bottom	1°C
Atlantic Ocean near New York (winter)	13°C
Atlantic Ocean near New York (summer)	18°C

5. LIGHT IN THE OCEAN

Tests show that sunlight goes down to an average depth 76 m. The greatest depth to where light shines is about 180 m. This is known as the *light zone*. Below the light zone, there is deep darkness. Why is this important? You are correct! Light is needed for photosynthesis. Does this give you the idea that plants can live only in the upper surfaces of the ocean? Collections of seawater show that your hunch is right. As we go below 76 m, we find no green plants. We find only animals and some non-green plants (fungi). The ocean is so thick with green plants that it is almost like a huge soup. And it is this soup that feeds all animals in the ocean.

- Ocean water temperatures can be measured.
- Ocean water is generally warmer near the equator.
- Ocean water temperature ranges from −2°C to 32°C.

PROFILE OF A GREAT SCIENTIST

Matthew Fontaine Maury (1806-1873)

Matthew Fontaine Maury was born in Virginia. As a midshipman, he had sailed around the world by the time he was 18 years old. An accident crippled him, and he was assigned to a desk job in the Navy.

Maury became interested in winds and ocean currents. He made studies of the Gulf Stream and described it as a "river in the ocean."

In 1855, he published the first textbook in oceanography. Maury is now considered to be "the father of oceanography."

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 18?

1. The oceans are solutions of salts.
2. The oceans are very cold or very warm.
3. Light passes only a short distance into the ocean.
4. Digging at the bottom of the ocean may produce valuable manganese.

II. In which paragraph do you find the answer?

1. What is ocean ooze?
2. Which is the warmest sea we know?
3. Why are there no plants at the bottom of deep oceans?
4. What are diatoms?

III. Knowing What and Why

1. The sun's rays
   a. warm ocean water and allow plants to grow.
   b. warm the fish and create ooze.
   c. form manganese and make nodules.
   d. create salts by decomposition.
2. Cold oceans can change temperature
   a. through evaporation.
   b. by concentration.
   c. by incoming warm currents.
   d. by the metabolism of their fish.
3. Ooze was probably formed from
   a. the skeletons of fish.
   b. the rust of sunken ships.
   c. dead plants.
   d. volcanic dust.
4. The "light zone" of the ocean refers to
   a. the water with the lowest density.
   b. the water with light-colored fish.
   c. the depth through which light passes.
   d. the smallest amounts of NaCl.

IV. True or false? Explain your answers.

1. Oceans are warmer near the equator.
2. Fungi are often found in ocean waters where there are no green plants.
3. Wherever oceans have more green plants, they also have more fish.

V. Unscramble the letters.

A L I S I T N Y (saltiness)

___ ___ ___ ___ ___ ___ ___ ___

E A U S O U C T (oceanographer)

___ ___ ___ ___ ___ ___ ___ ___

D N U E W A E R T R (below the water)

___ ___ ___ ___ ___ ___ ___ ___ ___ ___

T A B H Y C A P S H E (a diving ball)

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

T A C I C R (most northern part of Atlantic Ocean)

___ ___ ___ ___ ___ ___

Read the first letters down. You will get a kind of diver.

VI. For the Amateur Scientist

1. Devise (invent) a simple home experiment to show that evaporation increases saltiness of a solution.
2. If you live near an ocean, collect samples of ocean water. Shine a strong light through the samples. Describe your observations.

19

TARGET
What is the shape of the land below the oceans?

The Topography of the Ocean Floor

1. HOW DEEP IS THE OCEAN?

How deep is the lake on which you are fishing? There is an easy way to find out. Take a long fishing line, make a knot every six feet. Now tie a heavy lead sinker to one end of the line. Let the sinker down slowly into the water and count the number of knots that go below the surface. When you feel the lead sinker hit bottom, stop. If you have counted 10 knots, your lake is (10 × 6 = 60) 60 feet deep. You have used the oldest method known to find the ocean's depth. It is called *line sounding*.

2. LINE SOUNDING THE OCEAN

The method in Paragraph 1 was used by the *Challenger* and other early ships. Their lines were made of powerful cord. The lead sinker weighed 90 kg. The distance between knots was six feet. This distance is called a *fathom*. By dropping the line in hundreds of places, the reseachers could get an average depth.

3. ECHO SOUNDING THE OCEAN

When a sound wave hits a solid object, it is bounced back. Sounds that return to us are called ECHOES (EKohs). Sound travels through water at a speed of about 1525 m/s, over 1.5 km/s. If a sound wave travelling from a ship (right) takes one second to reach the bottom, it will take another second for the echo to return. It travelled 1525 m one way and 1525 m upward. In Fig. 139–1 A, the ocean is 1525 m deep. In Fig. 139–1 B, the sound took 2 + 2 = 4 s to return. The ocean is, therefore, 3050 m deep at Position B.

This method of finding the depth of the ocean is called *echo sounding*. The sounds come back as beeps. Not only will the sound tell us the ocean's depth, it will also tell us about the ocean's bottom. We can use echo sounding to locate underseas mountains, canyons, and valleys.

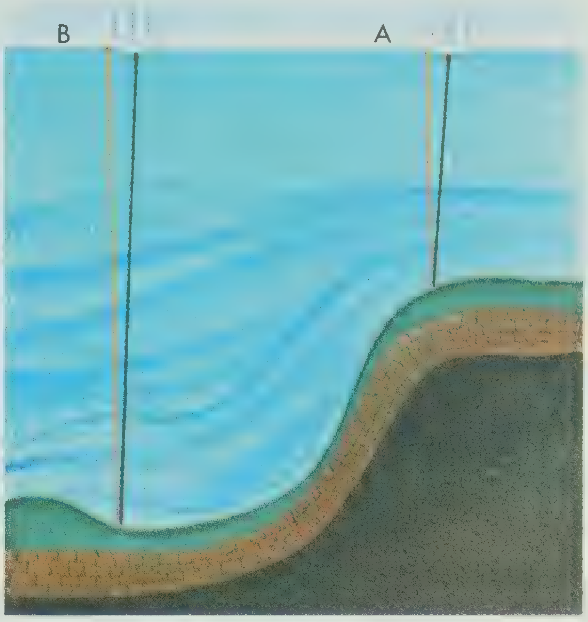


Fig. 139–1

Echo sounding uses sound waves.

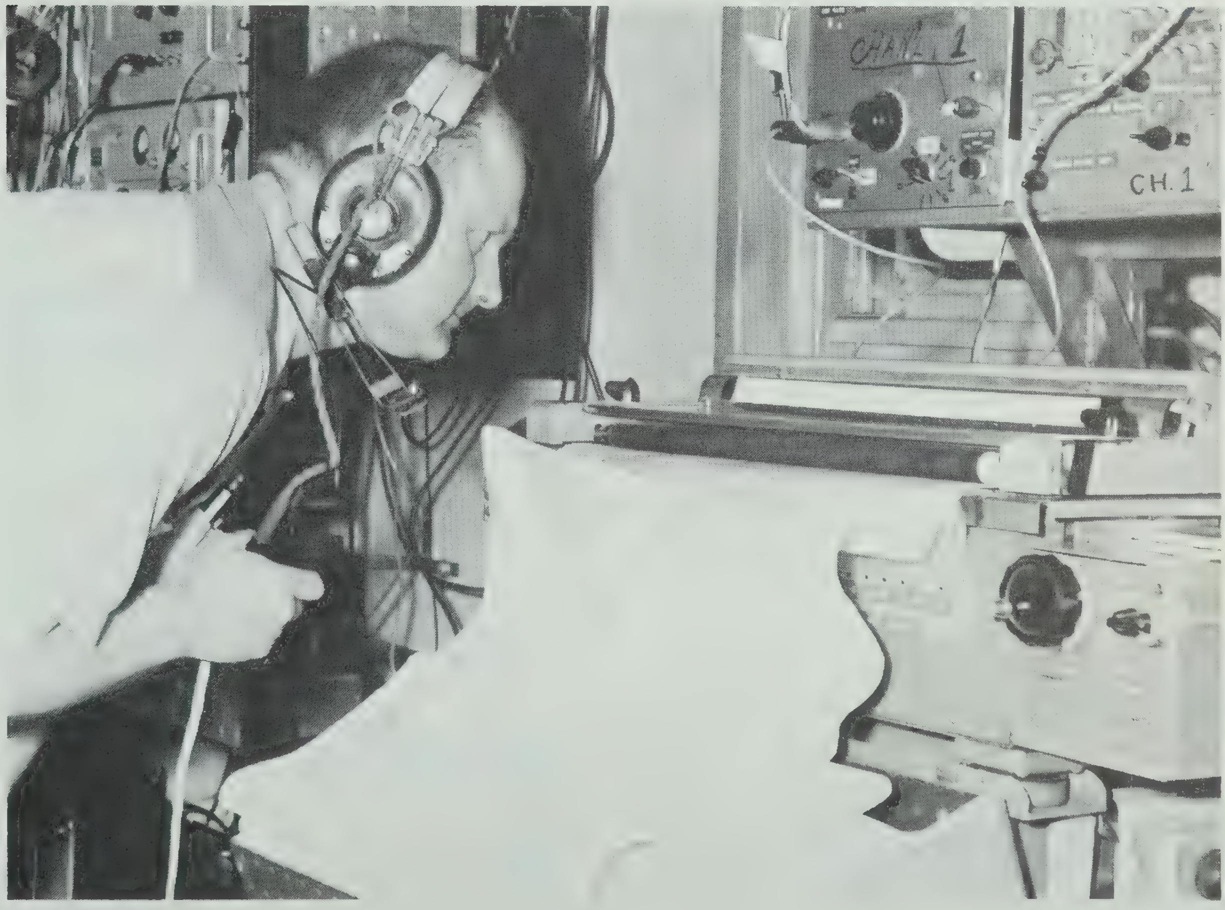


Fig. 139–2

Oceanographers use these echo sounders to explore the topography of the ocean.

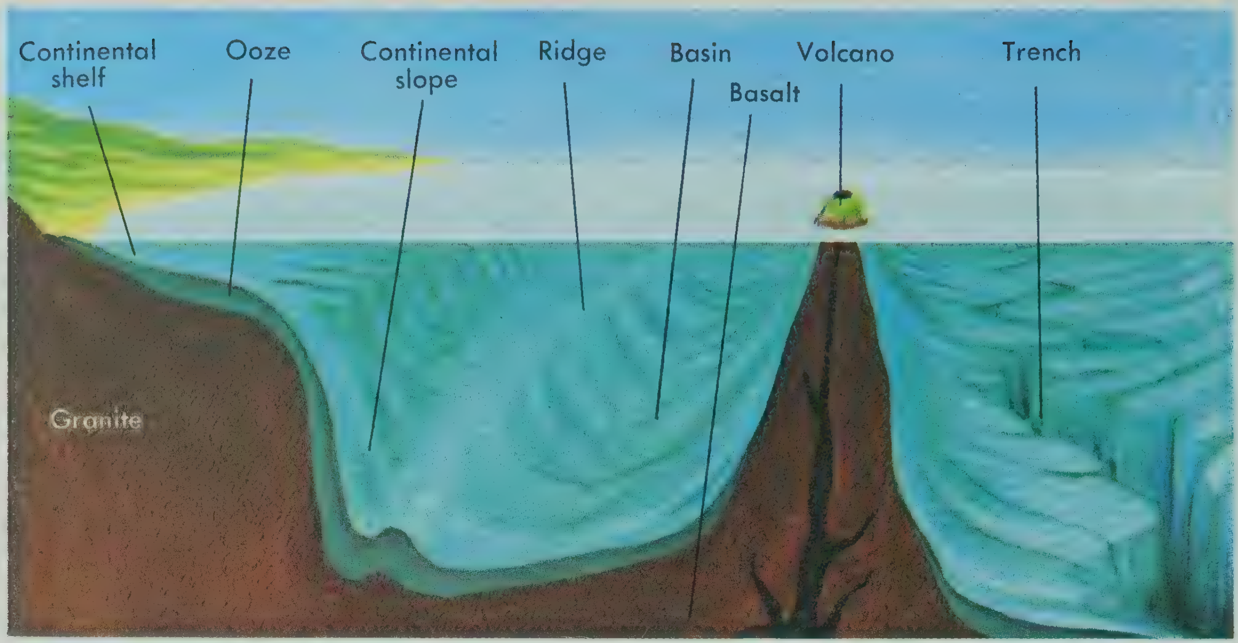


Fig. 140–1

The topography of the ocean floor shows its shape.

4. THE SHAPE OF THE OCEAN FLOOR

Topography (ta-POG-ra-fee) is the shape and elevation of land. Through soundings and U.R.V. exploration of the bottom of the oceans, we now have a pretty clear idea of the topography of the ocean floor.

As you leave the shore, the land slopes down gently under the water to a depth of 180 m. This first level is the *continental shelf.* Then the floor drops suddenly to a lower level. This second level is from 4 to 8 km deep. It is called the *continental slope.* The slope then drops to the floor of the ocean, the *basin.*

The basin is not smooth and level. It has several mountain chains called *ridges* and several very deep *trenches.* Just as on land, the mountain ridges have peaks, level plateaus and deep canyons. The ocean floor also has several volcanoes.

The first 4560 m of the bottom are ooze. Below the ooze, is red clay. Finally we reach the rocky part of the ocean bottom. At the very bottom, we find BASALT (buh-SALT). On top of the basalt layer is a layer of the

THE OCEAN'S LAND

Continental Shelf

Continental Slope

Basin

Ridges
Volcanoes
Trenches

lighter GRANITE (GRAN-it). Both of these rock layers are igneous rock. They were formed by cooling of the molten (melted) magma from which the rest of the earth was formed.

5. MOUNTAINS IN THE SEA

Just as the lithosphere has valleys and mountains, the ocean floor has canyons and mountains. Just off Hawaii, standing in the ocean, is the lofty *Mauna Kea*. It reaches 5200 m upward from the ocean floor and then sticks up out of the water another 4300 m – a total height of 9500 m, 650 m higher than Mt. Everest on land!

The Hawaiian Islands are really the peak of old volcanoes which rise from the floor of the Pacific Ocean. Not only are there high peaks, there are also very deep V-shaped canyons, some as deep as the Grand Canyon of Arizona.

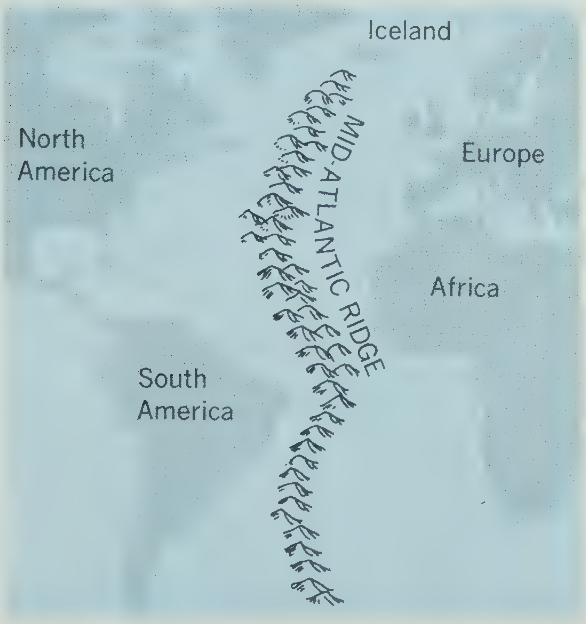


Fig. 141–1

The Mid-Atlantic Ridge cuts the Atlantic Ocean into two basins. The Easter Island Ridge is in the Pacific. The Indian Ridge is in the Indian Ocean.

In Paragraph 4, we spoke of mountain ridges on the ocean bottom. These large ridges have been mapped. The Mid-Atlantic Ridge is the longest. On the map in Fig. 141–1, you can see that it runs from north to south. It is about 16 000 km long. Its average width is about 1000 km. Get a good map of the world and find the Azores Islands (west of Africa). The Azores are called islands. Actually they are part of the Mid-Atlantic Ridge, sticking up out of the ocean.

6. THE DEEPS OF THE OCEAN

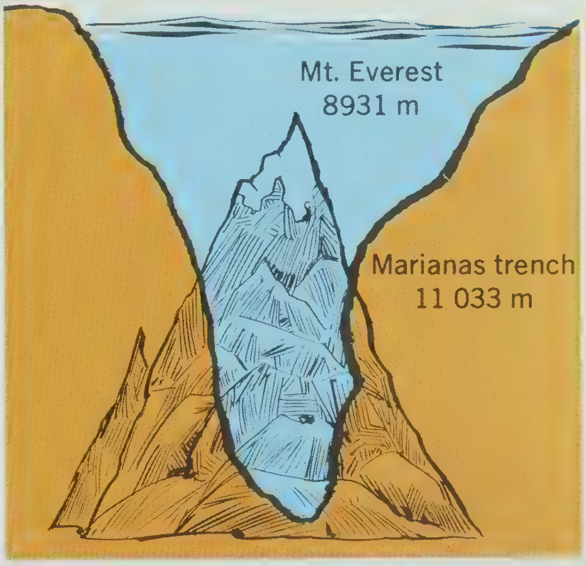


Fig. 141–2

If Mt. Everest were placed into the Marianas Trench, how many metres of water would cover it?

The *Challenger* thought she had located the deepest part of the ocean. Her report, in 1872, listed a spot in the Pacific near the Mariana Islands (near Guam) as 10 000 m deep–a little over 10 km. The latest soundings show the Marianas trench to be 11 033 m deep. This is over 11 km. The deepest spot in the Atlantic Ocean is about 9201 m (9 km) near Puerto Rico.

Some deeps or trenches are 160 km long and 160 km wide. There are seventeen such trenches. They are all close to the land, mostly near islands.

SOME WELL-KNOWN OCEAN TRENCHES

Name	*Located Near*	*Depth*
Marianas	Guam	11 033 m
Philippine	Philippines	10 497 m
Nares	Puerto Rico	9 210 m
Middle America	Eastern Pacific	6 660 m

YOU NOW KNOW

- Sounding is used to find ocean depths.
- The ocean bottom is made of basalt and granite.
- The shape of the ocean floor is formed by mountain ridges, volcanoes, canyons and trenches.

PROFILE OF A GREAT EXPLORER

Thor Heyerdahl (1914-)

For thousands of years, sailors have used the natural ocean currents to sail the seas. The Spanish explorer, *Ponce de Leon* (Pons-di-LEE-un) used the Gulf Stream to sail his ships from America back to Spain. The ships entered the Stream which carried them slightly north, along the U.S. eastern coast and then across to Europe.

The ancient *Incas*, the proud Indians of Peru, were able to sail to the Easter Islands in the South Pacific thousands of miles away. How?

In 1947, THOR HEYERDAHL, a Norwegian explorer-scientist, built a raft of very light wood and set sail from Peru. They sailed the entire distance of 6900 km by the force of the natural ocean currents. One hundred and one days later they landed on a small island near Tahiti.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 19?

1. The floor of the ocean is irregular.
2. Depths of ocean floors can be measured.
3. Echo sounding locates trenches.
4. The ocean basin shows ridges, volcanoes and trenches.

II. In which paragraph do you find the answer?

1. What is the indirect way of measuring the depth of the ocean?
2. Do some ocean mountains stick up out of the water?
3. Where is the deepest known part of the ocean?
4. What is the difference between an ocean ridge and an ocean trench?

III. Knowing What and Why

1. As you leave the shore the correct order of the sections of the ocean floor is
   a. basin—shelf—slope.
   b. shelf—basin—slope.
   c. shelf—slope—basin.
   d. basin—slope—shelf.
2. Which is the proper order from top to bottom?
   a. ooze—granite—basalt
   b. basalt—granite—ooze
   c. granite—ooze—basalt
   d. granite—basalt—ooze
3. The granite and basalt are examples of
   a. igneous rock.
   b. very old ooze.
   c. sedimentary rock.
   d. fossilized fish.
4. Sound travels through water at a speed of about
   a. 1.5 km/min.
   b. 1.5 km/s.
   c. 299 000 km/s.
   d. 110 m/min.

IV. Which word does *not* belong with the other three?

Example: second, metre, hour, minute.
The answer is *metre,* because second, hour and minute are time measurements.

1. kilometre, sounding, deeps, temperature
2. granite, ooze, light zone, basalt
3. salinity, slope, shelf, ridge
4. Nares, Marianas, Arctic, Philippine
5. ridge, deep, topography, salinity

V. Try These Problems

1. A line sounding in a lake is given as 12 knots. How many feet deep is the lake?
2. An echo sounder hears the return beep in 8 s. How deep is the ocean at that point?

VI. For the Artists

Copy Fig. 141–1 onto a large poster board. Use colors. Bring it to class.

VII. For the Science Reporter

Use a world almanac. Look up the deep spots in the world's oceans. Draw a table. Report to your class.

20

TARGET
What makes the ocean waters move?

The Restless Ocean Waters

1. THE "ANGRY" SEA

Have you ever heard the sea called "angry"? Have you ever heard the roar of the waves, seen the speed of the rolling waters and listened to the crash of the breakers against the shore? Then you will agree that "angry" is sometimes a good way to describe the sea. But the sea can also be calm and quiet as the waters move gently. What causes these movements? Where does all the force come from? Let us see.

2. THE MOVEMENTS OF WATER

The ocean waters can glide gently and move slowly. These movements are the *ocean currents*. Roaring, angry waters are called *waves*. The rocking of an earthquake beneath the seas makes giant waves called TSUNAMIS (tsoo-NAH-mees). Your experience at the beach has shown you that there are *tides* which are the rise and fall of the ocean waters at different times of the day. You will study tides in your next book in earth science. Let us examine waves and currents.

MOVEMENT OF OCEAN WATER

WAVES
CURRENTS
TSUNAMIS
TIDES

3. HOW WAVES GET STARTED

Stand a basin of water on a table. Using a three-speed electric fan, blow air at the surface of the water with slow, medium and high speed force. You have just seen the way all waves get started. Waves are movements of water caused by the high speed winds. Waves caused by slow winds are called RIPPLES (RIP-ulls). The huge waves are caused by strong winds blowing a long time in one direction.

What does a wave really look like?

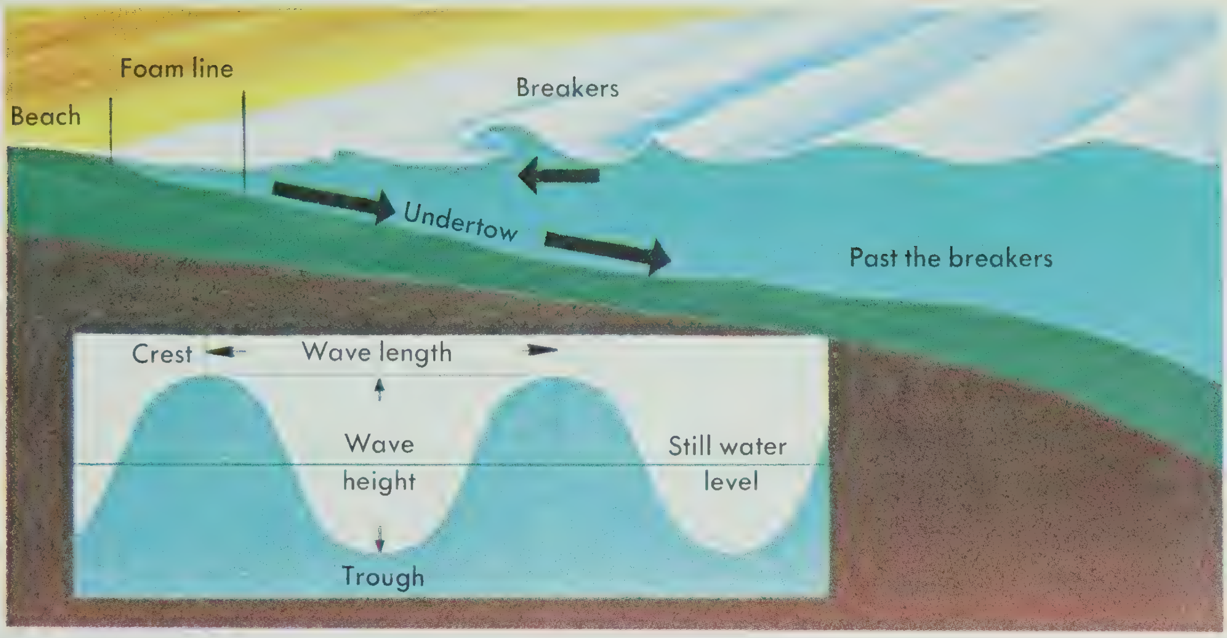


Fig. 145–1

The form of a wave is shown. Past the breakers, a body only moves up and down, not forward. This proves that the water does not really move forward.

A wave has a high spot called a CREST (KREST) and a low spot called a TROUGH (TRAWF). There are some waves that tower to 30 m. Waves move just a little more slowly than the winds which start them.

4. LET'S WATCH A WAVE AT THE SHORE

When the wave comes towards the shore, its bottom touches the bottom of the shore and it slows down. The crest does a forward roll and forms a smaller wave. Actually the water from far out is not moving in. It's only the *rolling motion*, the wave shapes, that move in. The crest moves forward and forms a *breaker* with a big crash and great force. Now the water rushes back and runs under the new wave which is rolling forward. As it rushes back, it pulls the sand along with it. This backward pull is called an *undertow*. This undertow can pull out and drown even the best swimmers. DANGER: When you feel strong undertows, leave the water at once!

5. WAVES SHAPE OUR SHORES

You have already learned that water wears land away (*erosion*) and that water builds land up (*deposition*). Waves are powerful forces. So their erosion actions and their deposition actions cause big changes in our seacoasts.

Waves cut into the shore to form *sea cliffs* and *sea caves*. The water is actually cutting shapes in the rocks. Shorelines are washed away and this action may destroy valuable harbors. The opposite of this action happens when the undertow meets the incoming waves and deposits sand offshore (away from the shore). As the

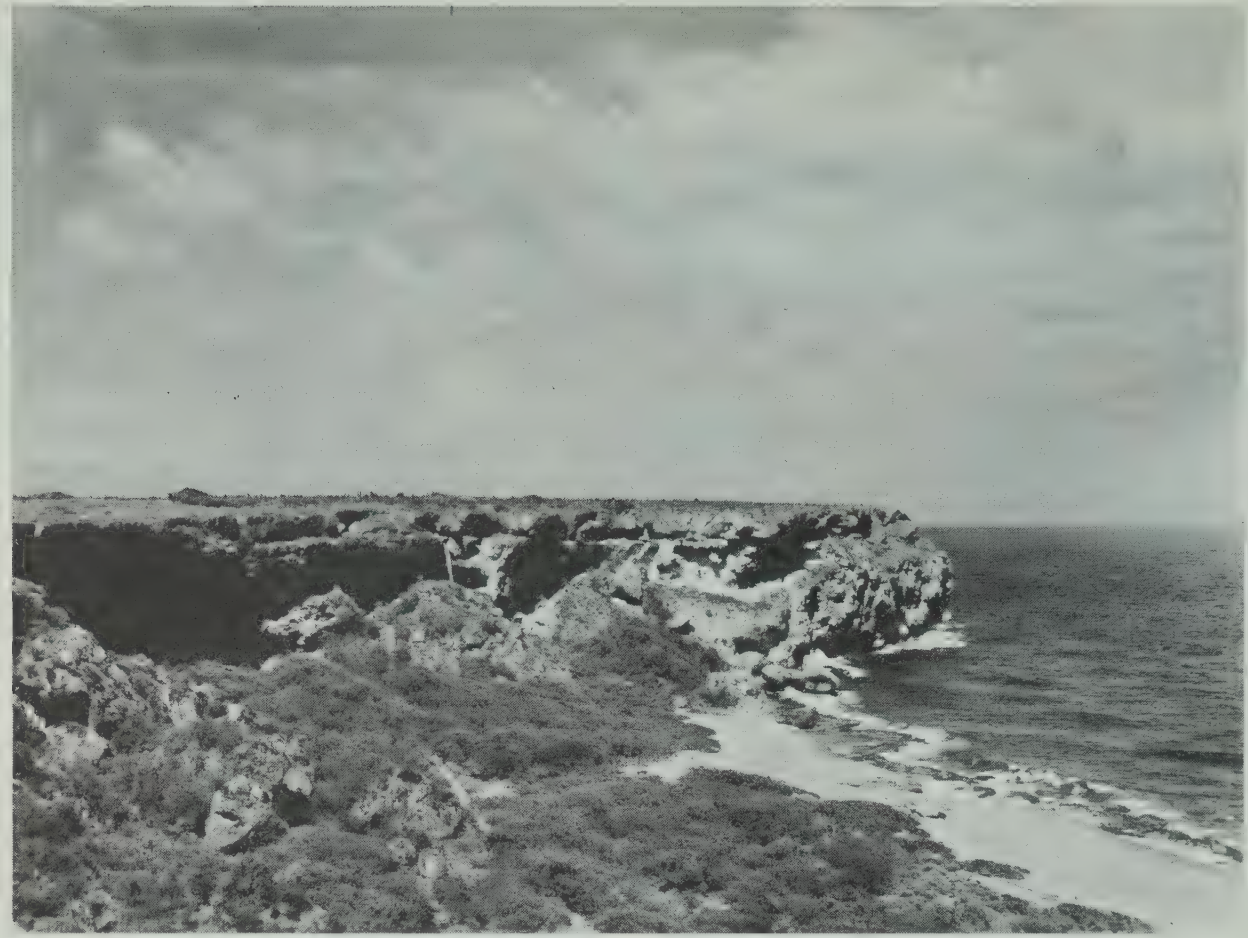


Fig. 146–1

This sea cliff at Mona Island, Puerto Rico, was cut by the action of ocean waves.

years go by, the sand gets higher and higher to form a *sand bar* which may stick out over the ocean. Jones Beach in New York and Miami Beach in Florida were formed as *bars*—not connected to the shore.

YOU NOW KNOW

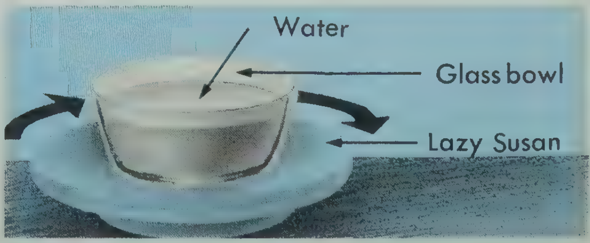
- Waves are started by wind movements.
- Crests, troughs, breaking and undertow depend on the strength of the winds.
- Waves cause erosion and deposition. They cut the shore and build sand bars.

6. THE CAUSES AND DIRECTIONS OF OCEAN CURRENTS

DO AND DISCOVER

Investigation 14: A. How does the earth's rotation cause ocean currents?

Place a basin of water on a Lazy Susan tray. Spin the basin gently in a counterclockwise direction (right to left). Observe. Let the water rest until it is still. Rotate the basin in the opposite direction (as shown below).

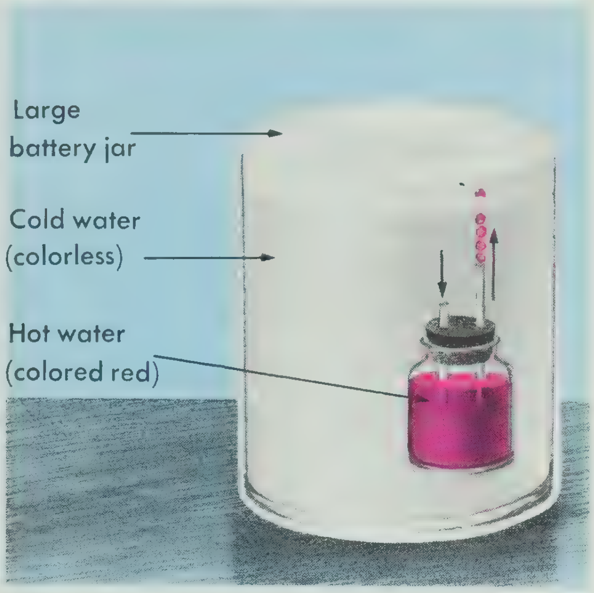


A

How does convection start currents in oceans?

Set up the apparatus shown. Observe the movement of the water.

B



Look back at Chapter 8, Paragraph 8. You saw that the rotation of the earth causes winds to curve clockwise in the northern hemisphere and counterclockwise in the southern hemisphere. The demonstration (A) shows the same is true of the oceans' waters.

Water at the equator is warm and expands. The winds and the earth's rotation move the water currents towards the poles. Near the poles, the cold water sinks and begins moving towards the equator. These movements are known as *density currents.*

7. WHERE ARE THE MAJOR OCEAN CURRENTS?

As you read this description, look at the map, Fig. 148–1. Some of the major currents are the Gulf Stream, the Japan Current, the Equatorial Currents and the Labrador Current. Currents that flow from the equator are warm. Currents that flow towards the equator are cold.

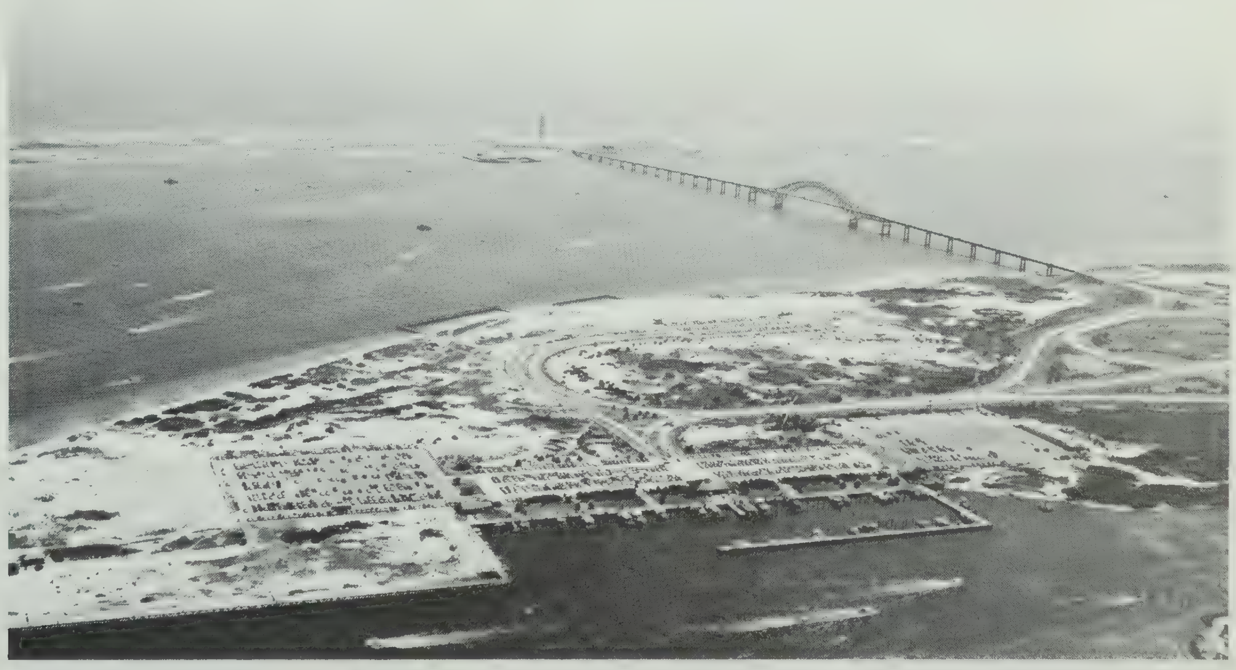


Fig. 147–1

This causeway connects the tip of Fire Island with Captree State Park, New York. Fire Island is really a sand bar. Can you explain how it was formed?

The Gulf Stream (warm) flows from the Gulf of Mexico, near Florida and Cuba. It first moves alongside the east coast of the U.S. Then it turns northeast and crosses the Atlantic to the British Isles. It then continues on to Iceland and Murmansk, an ice-free port on the Arctic Circle.

The Labrador Current (cold) starts in the Arctic Ocean and flows into the North Atlantic Ocean. It flows to Labrador, Newfoundland and New England. When it meets the warm Gulf current, the Labrador current sinks under it and returns the water to the equator.

8. OCEAN CURRENTS CHANGE CLIMATE AND WEATHER

We saw that climate is affected by latitude, winds and altitude. Now we can see that climate is also affected by currents. The warm Gulf Stream brings mild winters to England and Norway. At the same latitude, across the Atlantic, Labrador and Greenland have very cold winters. The Japan Current, a warm current, brings mild climate to British Columbia and Alaska. The Gulf Stream's current warms the continent as far north as New York.

Have you ever heard of a "pea souper"? It is the name given to the very dense fogs of London. These heavy fogs are caused when the warm, moist air from the Gulf Stream meets the cooler air from the Labrador Current. Such dense fogs are also found in Newfoundland.

YOU NOW KNOW

- Ocean currents are caused by winds and unequal heating.
- Ocean currents travel regular routes according to wind and convection laws.
- Currents help to regulate climate and weather.

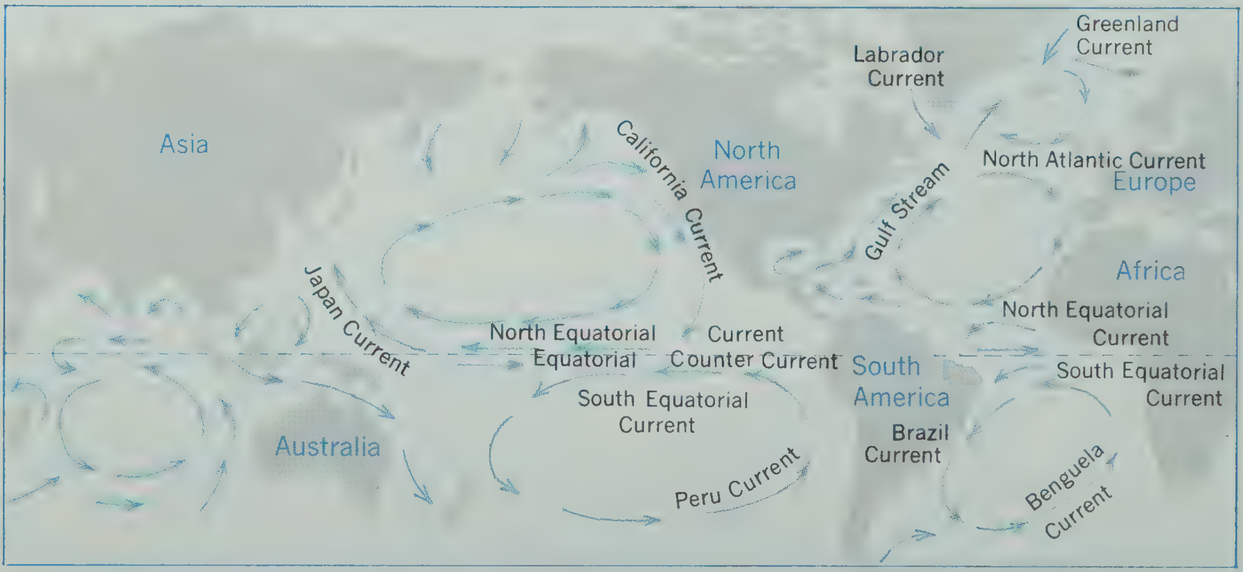


Fig. 148–1

Ocean currents of the world.

Warm Currents: Japan, Equatorial, Brazil, Gulf.

Cold Currents: Peru, Benguela, Labrador, California, North Atlantic.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 20?

1. Waves are ocean water movements that cause erosion and deposition.
2. An undertow is very dangerous.
3. Ocean currents change climate and weather.
4. Tides rise and fall at different times of the day.

II. Explanation, please . . . answer in one or two sentences.

1. How are sea cliffs formed?
2. How does an undertow start?
3. What are the parts of a wave?
4. What is the explanation for the dense fogs of London?

III. Knowing What and Why

1. The mild winters in England are caused by
    a. the warm Gulf Stream.
    b. heavy fogs which serve as a blanket.
    c. the Labrador current.
    d. sharp undertows.
2. Ocean water-movement is caused by tsunamis, waves, currents and
    a. ooze.
    b. solar radiation.
    c. tides.
    d. rotation.
3. Which of the groups of ocean currents is *all* warm?
    a. Japan—Brazil—Peru
    b. Labrador—Japan—Brazil
    c. Gulf—Japan—Brazil
    d. Gulf—Japan—North Atlantic
4. Ocean currents travel the routes they do because of
    a. rotation and revolution.
    b. rotation and convection.
    c. convection and tsunamis.
    d. convection and weather.

IV. Understanding the Diagrams

1. Why do the people past the breakers bob up and down?
2. Why are the people not carried in towards the beach?
3. From where to where is the wave length measured?
4. From where to where is the wave height measured?

V. State the difference clearly in your own words.

1. What is the difference between *ripples* and *waves?*
2. What is the difference between an *undertow* and a *breaker?*
3. What is the difference between *erosion* and *deposition?*
4. What is the difference between a *bar* and a *causeway?*

VI. Do you agree or disagree? Explain why.

1. Ocean currents are controlled by the same force as winds.
2. Sandbars take a long time to form.
3. Shorelines can be kept even by building stone jetties or walls.
4. The sun has something to do with causing waves.

VII. For the Science Reporter

Write to the National Science Foundation, Washington, D.C. 20550. Ask for a copy of their free booklet, *Deep Sea Drilling Project.* Write a report of the drilling ship, the *Glomar Challenger,* describing its construction and the research it is doing. After you are finished, cut up the booklet and illustrate your report with the pictures you have gotten.

21

TARGET
What plants and animals live in the ocean?

The Citizens of the Ocean

1. THE CRADLE OF LIFE

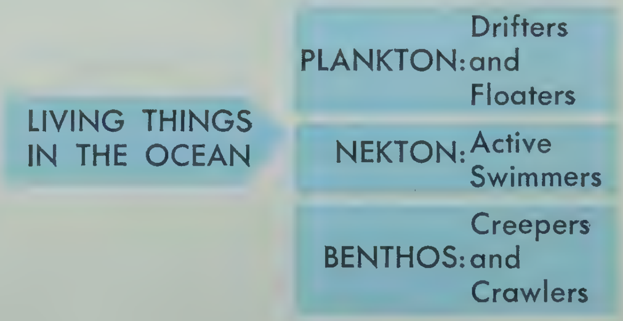
The earliest fossils that scientists ever found are really the remains of creatures that lived in water. The oldest fossils were of single-celled creatures. They are found in the sedimentary rock formed under water. TRILOBITES (TRY-lo-bites) are fossils of ancient water crabs. AMMONITES (AM-ah-nites) are fossils of ancient water snails. The chalk in the White Cliffs of Dover, England, are the skeletons of ancient shellfish living in water.

The simple organisms gave rise to more special types. Later some types left the water to live on the land. These gave rise to the land animals we know. All this happened about three billion years ago.

What has happened in the ocean in the meantime? There are still some creatures living in the sea today that have not changed at all in billions of years! One of these is the *horseshoe crab*. Another one is the strange fish called a COELACANTH (SEE-la-kanth). Let us see what life exists in the oceans.

2. THE "NATIONS" OF THE SEA

One good way to understand the lives and habits of ocean life is to describe where they live and how they move. Look at the chart below. Remember that each group has many members. Each group is *adapted* (fit) to live in its own environment.


LIVING THINGS IN THE OCEAN
PLANKTON: Drifters and Floaters
NEKTON: Active Swimmers
BENTHOS: Creepers and Crawlers

3. THE "LITTLE LEAGUE" PLANKTON

We know that sunlight reaches down to about 75–180 m below the ocean's surface. Fish up a bottle of seawater from the sunlit surface and examine it under a good microscope. A new world comes into view.

The largest number of creatures you see are tiny single green cells called diatoms. The cell is inside a tiny shell made of silica. They resemble the crystals of snowflakes. Another type of microscopic creature is a red-colored cell with two little hairs or "whips." Sometimes, there are so many millions of them in the Gulf of Mexico and the sea near California that the tides are actually colored red! A third kind are the light-flashing algae. These give off flashes like fireflies and make millions of dancing pinpoints on the surface of the ocean. Along with the algae, there are millions of protozoa. One type, the *forams,* have beautiful lime shells.

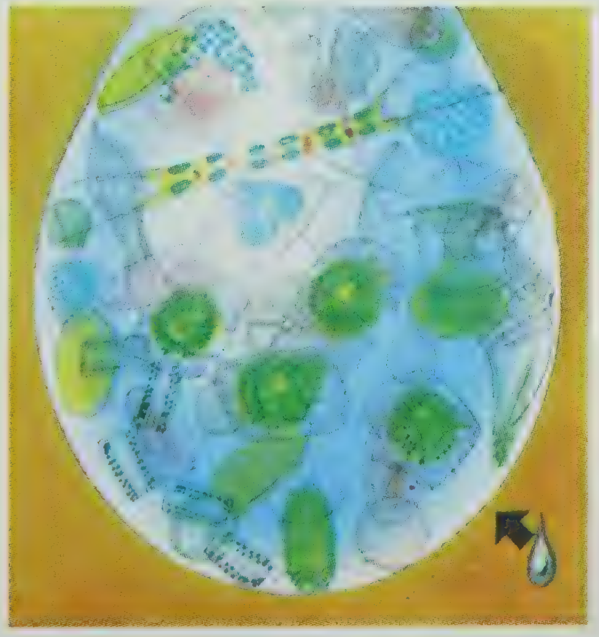


Fig. 151–1

Samples of microscopic plankton.

YOU NOW KNOW

- Life began in the sea with very simple creatures.
- Sea life is classified as floating, swimming or creeping.
- Plankton consists of microscopic algae and protozoa.

4. THE "BIG LEAGUE" PLANKTON

The "big league" plankton are large, many-celled algae called *seaweed.* Most of these are flat, so that it is easy for them to float. Some have air-bladders to give them more buoyancy. Some are branched. There are two very common seaweeds that you may have seen at the beach. One is the light green sea lettuce. Another one is a branched red alga.

The biggest seaweeds are the brown seaweeds. They contain a brown pigment in *addition* to the green chlorophyll. *Kelp,* a large brown seaweed, lives in cool ocean

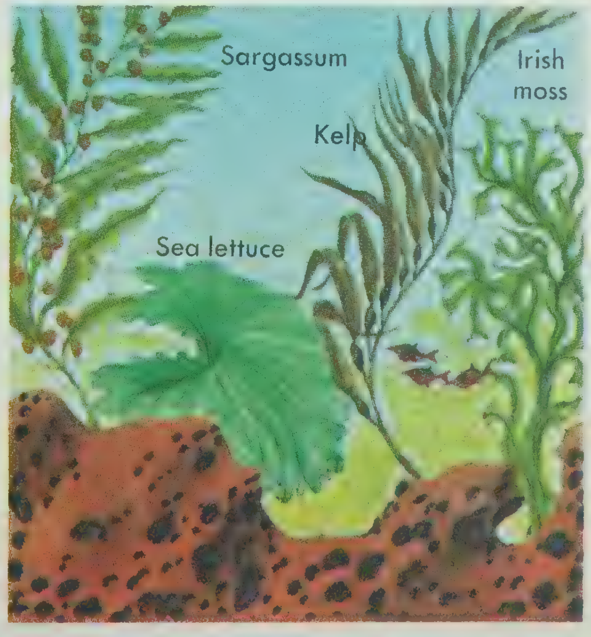


Fig. 151–2

These are examples of large plankton.

waters, especially near the U.S. Pacific coast. There are giant kelps that are 60 m long.

In old days, sailors would return from trips in the North Atlantic telling tales of how their ships were trapped in the Sargasso Sea. The Sargasso Sea is an area in the Gulf Stream, near the West Indies. According to these tales, thick growths of tangled seaweeds floated in this area. The ship became tangled and could not sail through. Of course, these sailors had good imaginations. But the Sargasso Sea has earned its name of "floating sea jungle." Long, tangled *sargassum weeds*, a brown seaweed, float along with the help of their air-bladder floats. Why does sargassum grow so well at this spot? This is because of the calmness and the warmth of the water in the center of the Gulf Stream current. Of course, living happily in this "jungle" are countless fish, shrimps and crabs.

5. SALTWATER FISH

It would take a whole book to begin describing all the fish that live in the ocean. Fish, of course, have tails and fins and are powerful swimmers. They have well developed gills for breathing. Fish that live in deep, dark waters have tiny eyes. Most surface fish, such as the sailfish and tuna, have blue tints. Mid-level fish are whitish or silvery. Very deep ocean fish are

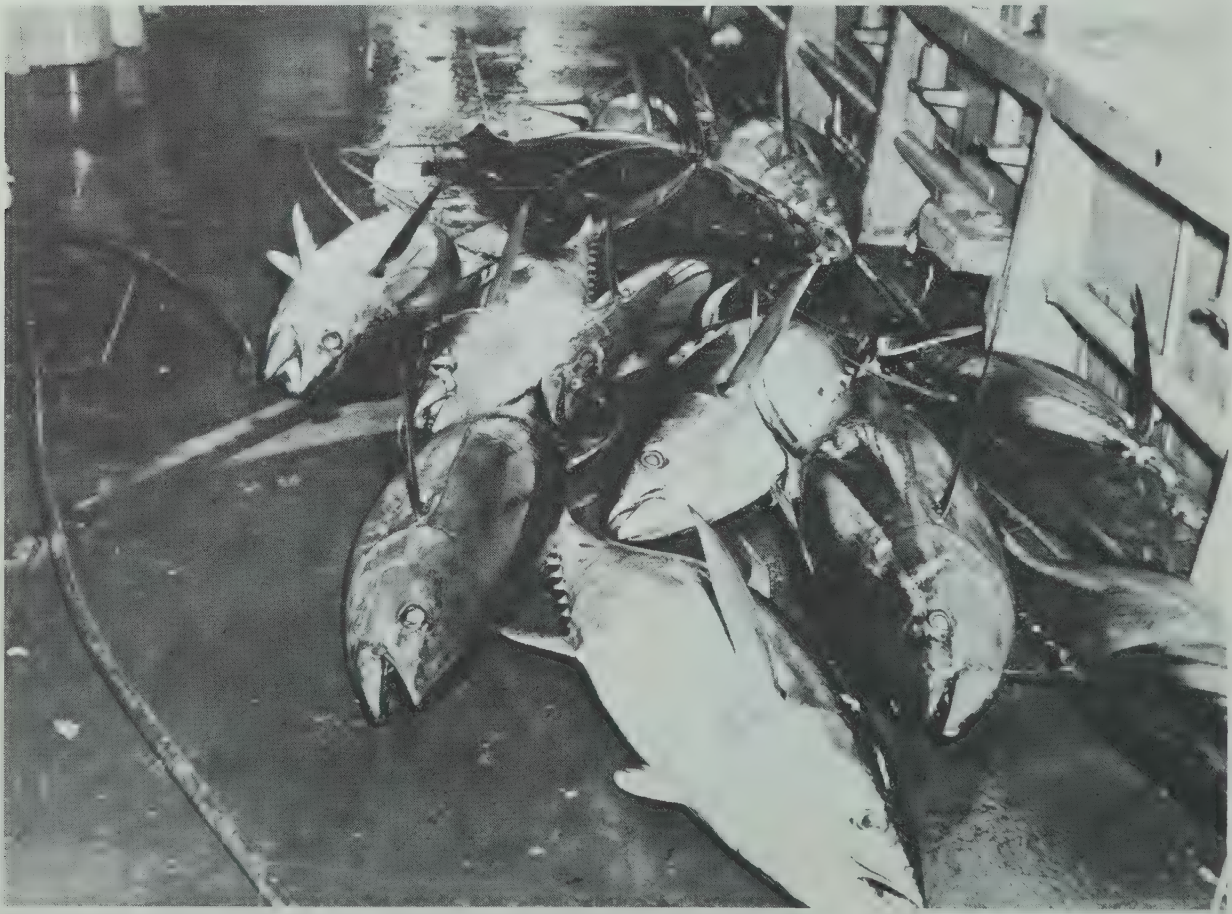


Fig. 152–1
These tuna are good fish for eating. Tuna fishing is a big industry.

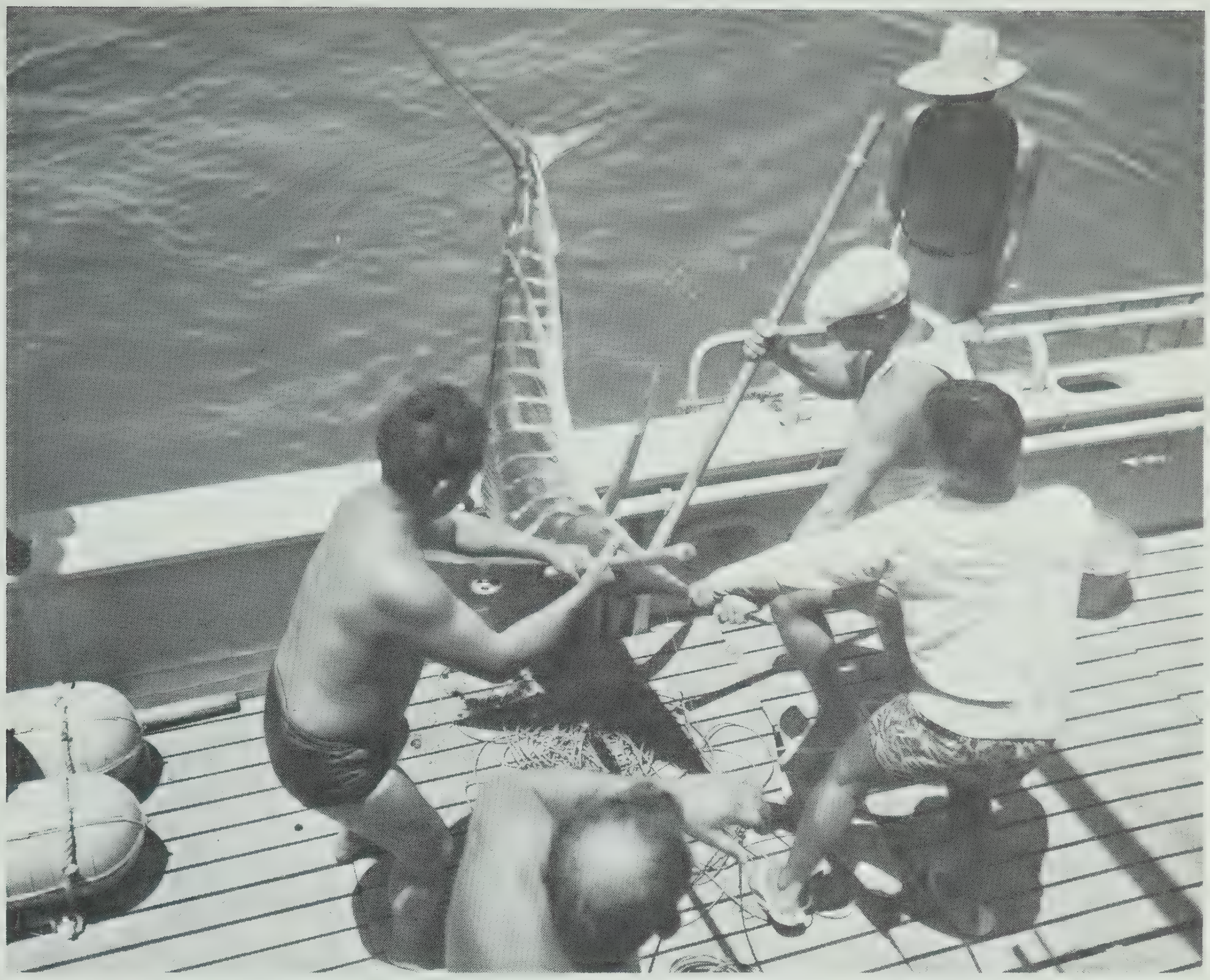


Fig. 153–1

The blue marlin is one of the biggest fish.

dark purple, brown or black. Fish vary in size, weight and color. Among the largest fish are the swordfish and the blue marlin. The largest of our food-fish are the tuna, the cod and the salmon. Sharks, skates and rays are very primitive fish. They have a reputation for having sharp teeth. They are not good swimming companions.

6. OUR CLOSEST RELATIVES IN THE OCEAN

Human beings belong to the group called *mammals*. Mammals have bodies covered with hair and breathe air with lungs. Female mammals have glands that produce milk to feed their young.

Mammals in the ocean include the whales, the seals, the sea cows and the porpoises. The whale is a huge animal that has its nostrils way up on its forehead. To breathe, the whale comes up over the water and blows out a steamy breath. Then he takes a deep breath and goes under again for about 15 to 20 min. The porpoises and dolphins are very smart and playful animals. Porpoises have even been trained to take commands from humans. In the Sealab, a porpoise called Tuffy was trained to carry messages to the bottom of the sea.

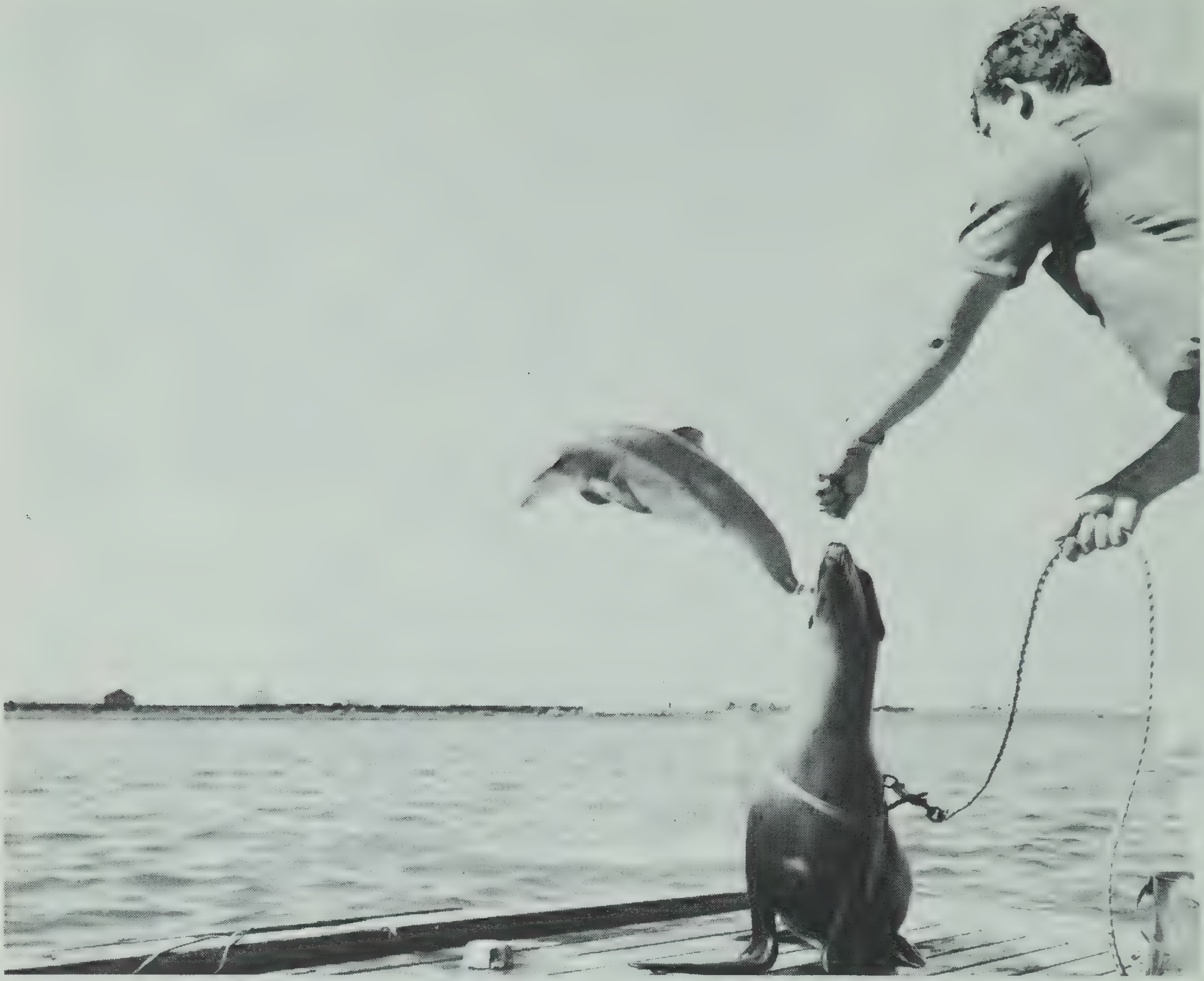


Fig. 154–1

Tuffy the porpoise jumps high out of the water. The trainer at the right offers a seal a reward. Both these mammals are smart enough to be trained.

7. THE CREEPERS AND THE CRAWLERS

This group, the benthos, are INVERTEBRATES (in-VER-ti-brayts), animals *without* backbones. These are the simple sponges of many shapes and colors which grow attached to the bottom and to rocks. Starfish and sea urchins are common. Starfish can regrow lost arms which come in sets of 5, 10 or 15.

Jellyfish move by whipping their tentacles. As some of us have found out for ourselves, the tentacles can also sting their enemies. The *Portuguese man-of-war* is a huge colony of jellyfish that can sting large fish for food.

The lobsters, shrimps and crabs are related to insects on land. They have a strong shell and large, jointed legs.

Shell-covered invertebrates are called *mollusks*. They have either a single shell like the snail or two shells like clams, oysters and scallops. They burrow in sand and creep very slowly. Squid and octopuses also belong to this group.

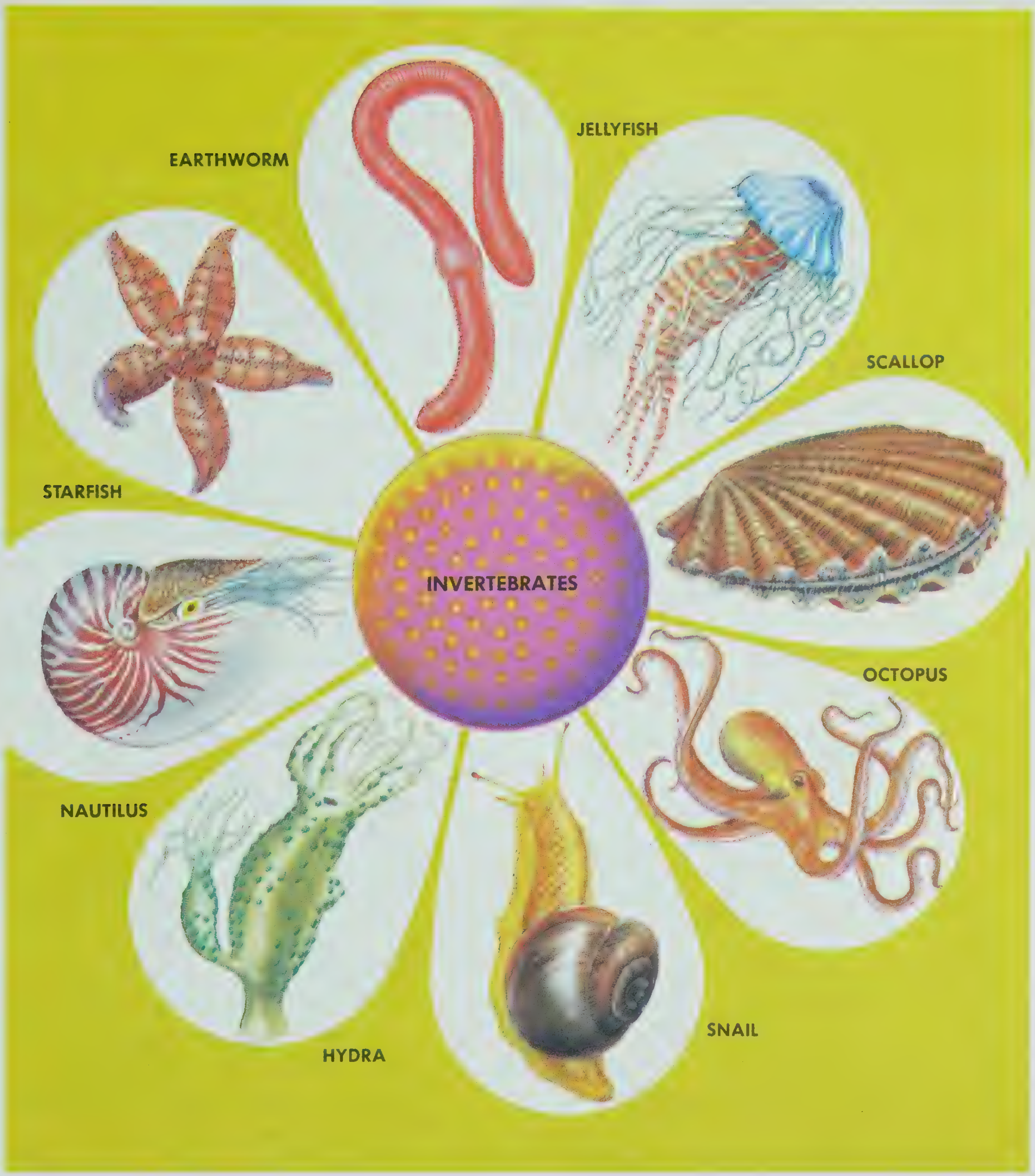


Fig. 155–1
Invertebrate animals. All except the earthworm live in water.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 21?

1. Life in the sea is floating, swimming or creeping.
2. Whales are mammals.
3. Life began in the sea.
4. Lobsters are related to insects.

II. In which paragraph do you find the answer?

1. What are mollusks?
2. For what is the Sargasso Sea known?
3. What determines colors of fish?
4. What are invertebrate animals?

III. Knowing What and Why

1. A jellyfish moves by use of
   a. feet.
   b. whippers.
   c. tentacles.
   d. fins.
2. Whales breathe
   a. air into lungs.
   b. water into gills.
   c. water into the spout.
   d. air into the mouth.
3. Tuna, cod and salmon are
   a. primitive fish.
   b. relatives of sharks.
   c. plankton.
   d. large, edible fish.
4. Seaweeds are
   a. single-celled ocean fungi.
   b. green fish.
   c. many-celled algae.
   d. invertebrates.

IV. True or false? Explain your answer.

1. Living things in the ocean are fit for their environment.
2. Green plankton is found nearer to the surface of the ocean.
3. Seaweeds, although they are plants, are different from land plants.

V. For the Science Reporter

1. Is there a museum of natural history or an aquarium in your city? Visit the exhibits and look for sea creatures.
2. Visit a local seafood store. See how many types of fish and shellfish you can recognize.

VI. For the Amateur Scientist

Would you like to start a saltwater aquarium? You may be able to keep saltwater fish and plants. Complete directions can be found in *Investigating Science*, page 234 and 235. Publisher: American Book Co.

VII. Go and Discover

Visit a local fresh seafood store. Ask the dealer to let you inspect his stock. How many can you identify? If you have a camera, it would be fun to take some pictures.

22

TARGET
What useful things do we get from the oceans?

Gifts from the Sea

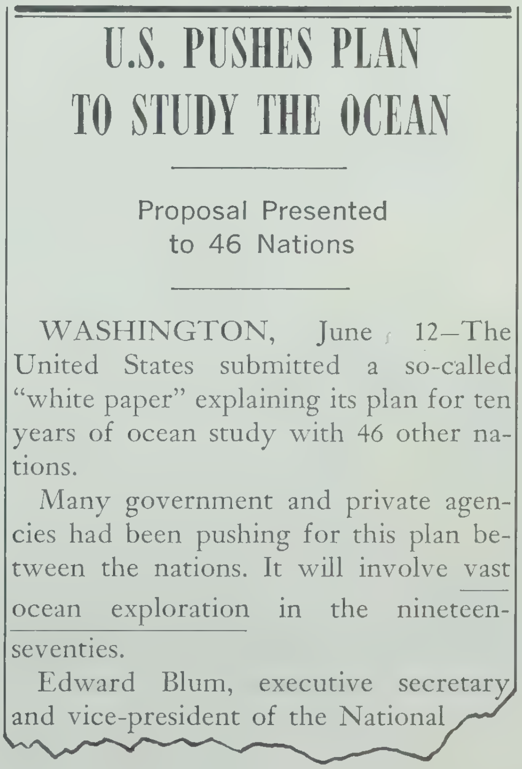
1. OUR OCEAN TREASURE HOUSE

Life started in the ocean millions of years ago. Today, more than ever, man is turning to the ocean for food and for other valuables. The science of oceanography is one of the fastest-growing sciences. Our government and other governments may soon be cooperating in huge projects to realize new hopes in the seas.

2. THE FOOD CHAIN

"Big fleas have little fleas
upon their backs to bite 'em;
And little fleas have littler fleas,
and so ad infinitum."

This rhyme tells us about *interdependence;* plants and animals depend upon each other. The green plankton, as you know, make food through photosynthesis. In turn, the nekton (free-swimming) animals eat the plankton. Some of the fish and whales have huge strainers which take the plankton and algae out of the ocean soup and into their stomachs.



U.S. PUSHES PLAN TO STUDY THE OCEAN

Proposal Presented to 46 Nations

WASHINGTON, June 12—The United States submitted a so-called "white paper" explaining its plan for ten years of ocean study with 46 other nations.

Many government and private agencies had been pushing for this plan between the nations. It will involve vast ocean exploration in the nineteen-seventies.

Edward Blum, executive secretary and vice-president of the National

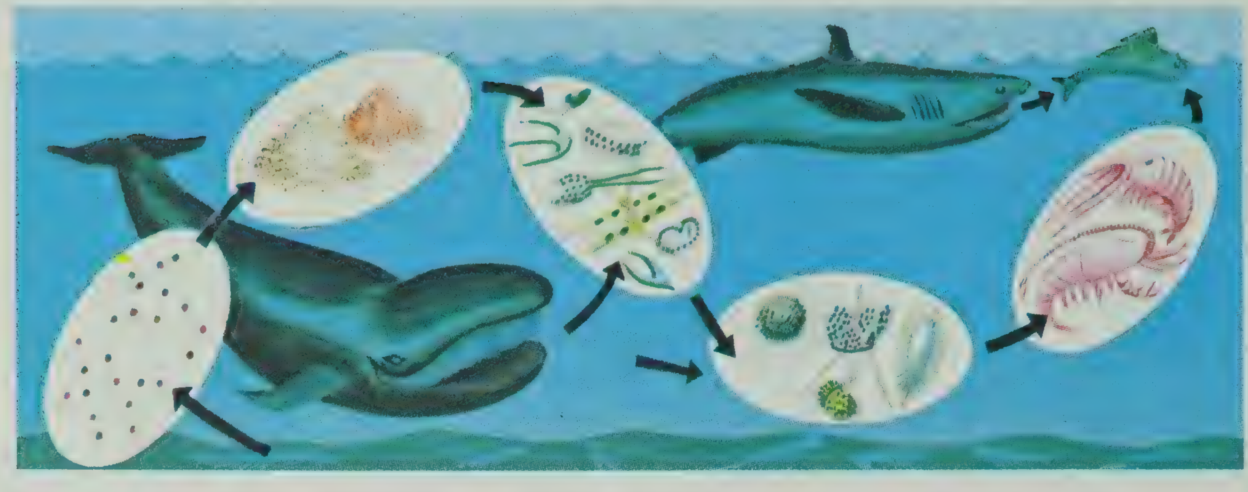


Fig. 158–1

This shows us how the food chain works.

The larger fish eat the smaller fish and both of them are food for sharks, seals and whales. Humans are not the only ones who like lobsters. We may prefer a shrimp salad or baked clams, but large fish are quite satisfied with the raw meat.

This interdependence is called the *food chain.* If the relationship depends on many living things, we call it a *food web.* Scientists have estimated that six tonnes of fish need 60 t of smaller things to eat. These smaller organisms need 600 t of plankton. Next time you eat tuna fish, think of what he must have eaten in the food chain to provide you with a sandwich!

Fig. 158–2

This man has just fished these lobsters out of the sea. Many people will enjoy a lobster dinner.

3. SEAFOOD FROM A FARM?

People have used seafood all through civilization. Fish, shellfish and other animals from the sea have been used for food and food oils. But modern scientists are not satisfied with just catching fish by net. There are new devices which can actually "suck up" fish from the ocean bottom. Fish hatcheries are shallow pools where fish eggs are protected until the tiny fish are born. Then they are turned loose in the ocean. "Lobster farms" are pools or tanks where young lobsters are grown and then turned loose in the sea to multiply.

New research has produced FPC—*fish protein concentrate*, or "fish flour." Thousands of fish, their entire bodies, are put through a special mill that grinds them and removes the water (dehydration). The dried solids, when mixed with soups, milk or bread, increase the nutrition value. A slice of bread, baked with FPC, is estimated to have the same nutrient value as a steak and for only a few pennies.

4. AQUACULTURE OR AGRICULTURE?

Getting nourishment from the sea has created a new industry, AQUACULTURE (AKWA-kul-chur). Aquaculture is farming the sea. Imagine a ranch in the ocean. We could stock a given area with special fish, provide the fish with special plankton, control its temperature and salinity.

The Japanese are first in the world in developing aquaculture. They raise huge quantities of fish and seaweeds. Scientists have been experimenting with growing a blue-green alga called CHLORELLA (klo-REL-uh). This edible, nutritious alga reproduces at amazing speed. In twenty-four hours, millions of these cells are

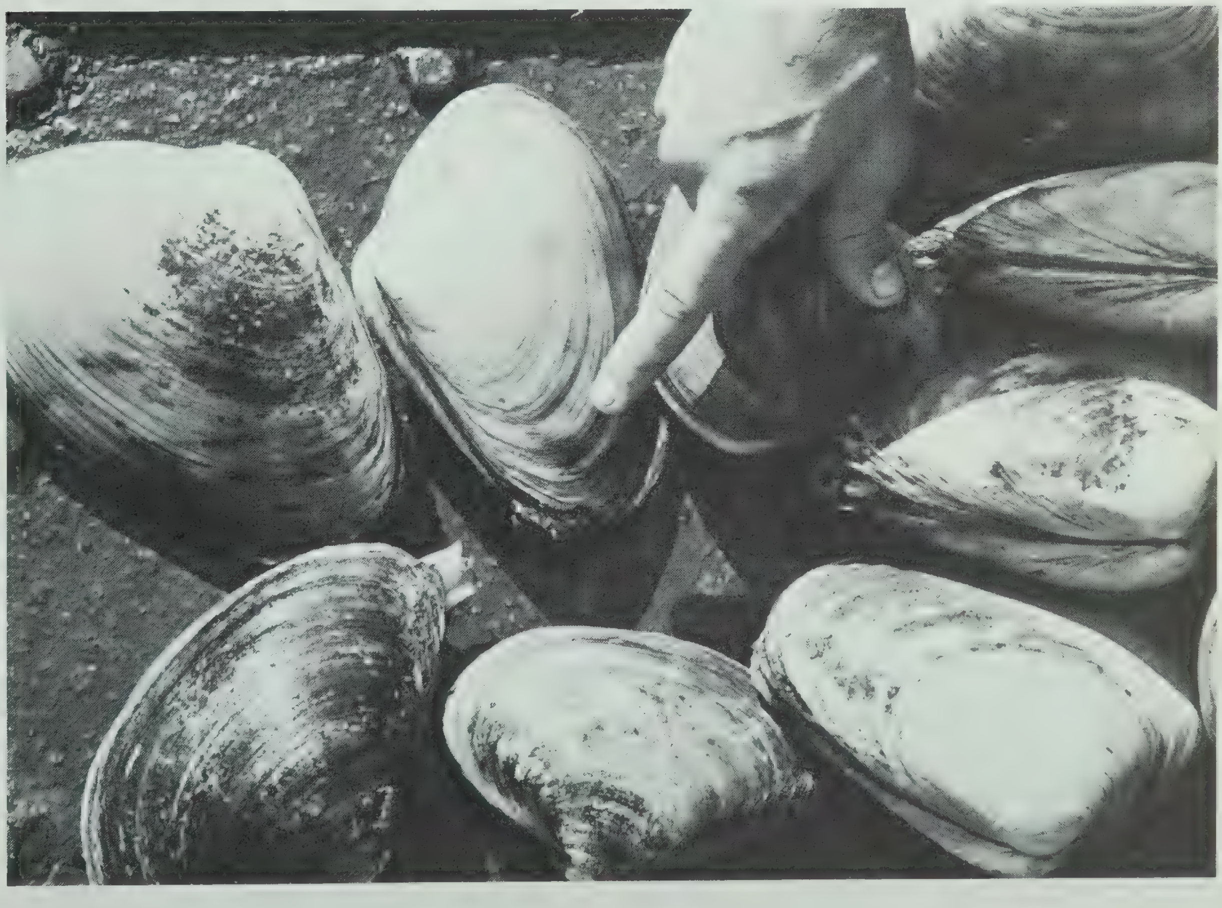


Fig. 159–1

Clams are a source of nourishment. How many shells does a clam have? How many shells does an oyster have?

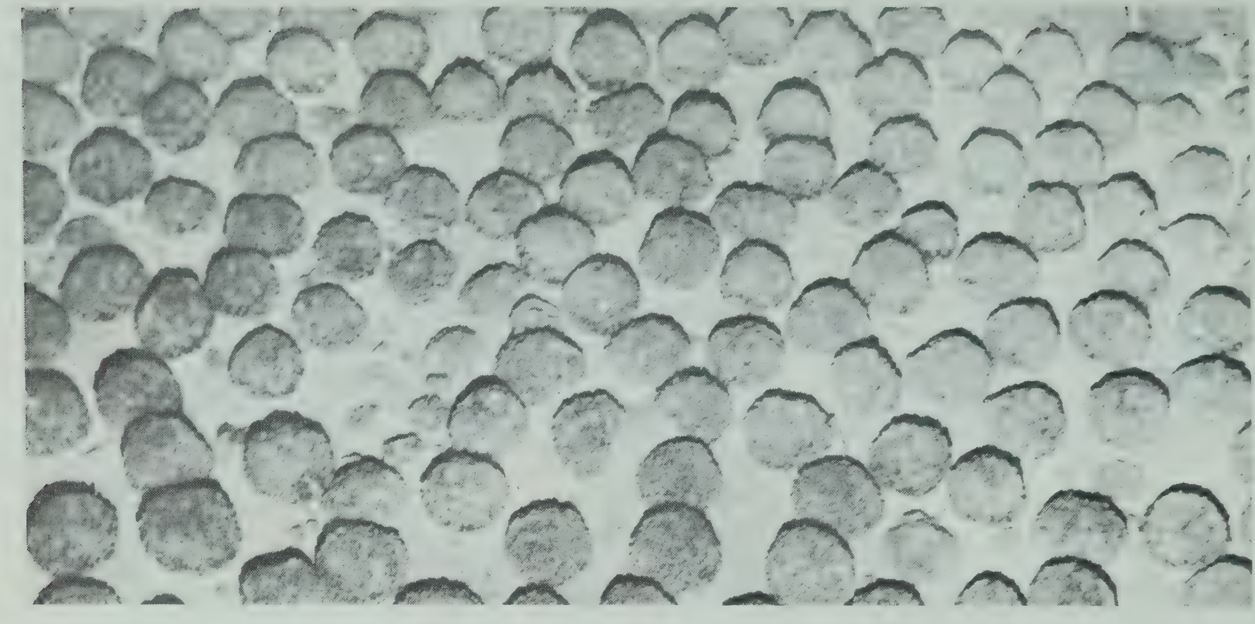


Fig. 160–1

These manganese nodules were found on the ocean bottom—5276 m deep. How deep is this in kilometres?

created. They are then used as food for fish, animals and humans. In a world of imagination and science, people will not have to go hungry.

YOU NOW KNOW

- Living things in the ocean depend on each other for food. This sets up a food chain.
- Food from the sea includes fish, and other sea animals.
- Aquaculture is the science of growing useful plants and fish in the sea.

5. MINERALS FROM THE SEA

A dredge can take enough manganese nodules from the ocean bottom to supply half of all the manganese needs of the U.S. But the nodules contain other treasures. They also contain cobalt and nickel. Imagine having a mine at the bottom of the ocean!

We have spoken several times of extracting salt (NaCl) from the sea. You must remember that there is an almost unlimited supply in the ocean. Often the sun evaporates enough water to give us pure salt!

The chemicals, bromine and magnesium, are removed from seawater which contains magnesium bromide. Bromine is used in manufacturing photographic film, medicines and "anti-knock" gasoline.

The seaweed, kelp, is an important source of iodine. If you were driving along the shores of Nova Scotia, you would see natives in rowboats raking in large tangled masses of seaweeds. The seaweeds are bundled and dried. A substance called *algin* is removed from it. The algin is used in manufacturing ice cream. The famous Irish Moss, made from dried and bleached seaweed, also is used in medicine to soothe mucus membranes.

6. THE OCEANS AND THE ENERGY CRISIS

The petroleum oil supply of North America is a large one—about 6% of the world's supply. But as industries grow, more and more oil is used. More people drive cars. More oil is used to generate electricity for our home appliances. More population requires more fuel oil to heat our homes. Scientists have known for a long time that our oil supply might be running short.

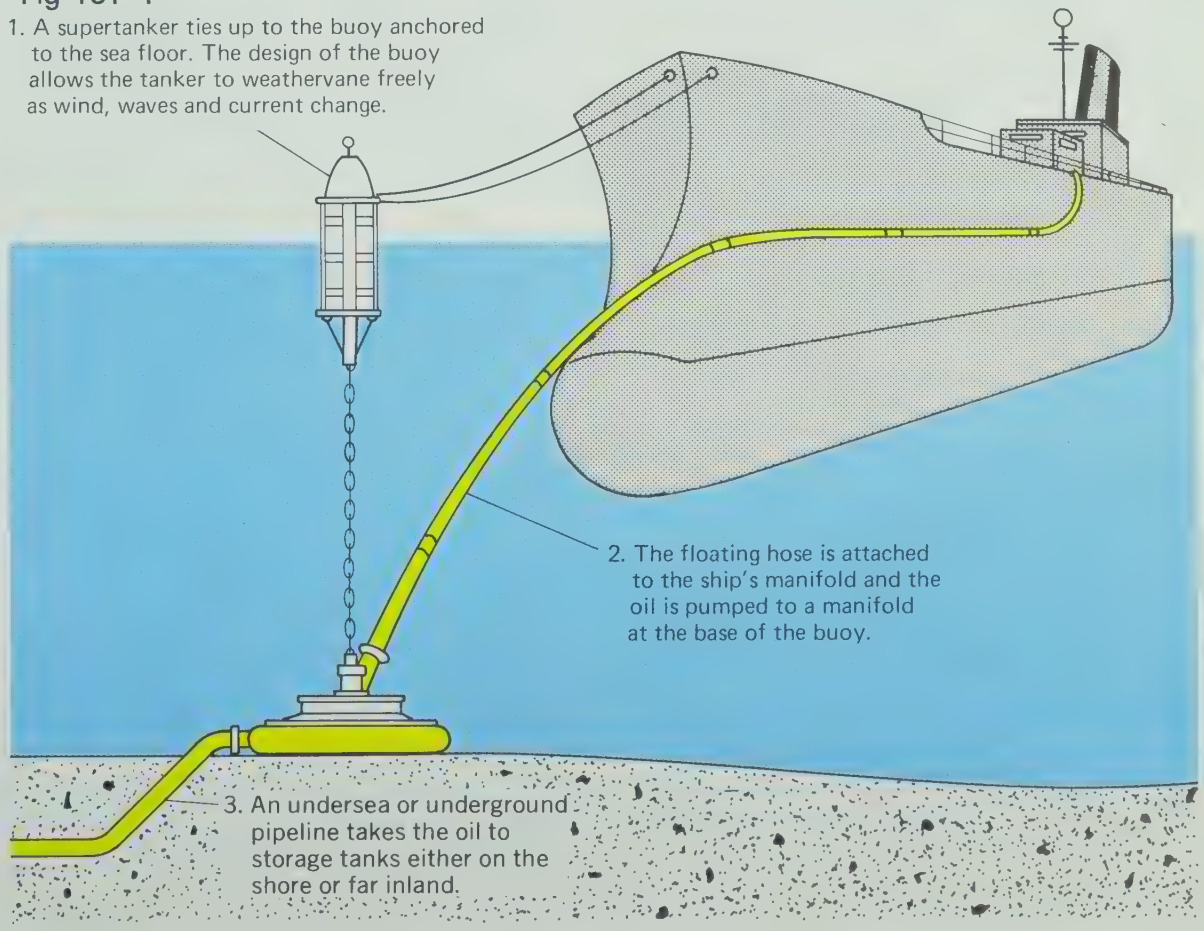
In the fall of 1973, a political crisis developed in the Middle East. The Arab oil-producing countries, which have 53% of all oil reserves in the world, reduced their supply to Europe, Japan, and North America. This produced an *energy crisis*. The U.S. Congress quickly approved the building of a huge pipeline to carry oil across Alaska to warm ports for shipment to the South. Many governments proclaimed new energy-saving regulations. Countries around the world took a new look at the oceans as a source of oil.

7. OFFSHORE OIL

It has been known since the 1930's that there are vast supplies of oil and natural gas below the continental shelf. This large ledge has been explored off the coasts of Louisiana, Texas, California, Nova Scotia and Labrador. Some geologists believe there may be nearly as much oil under the shelf as there is on land.

Special drills are mounted over the water above the continental shelf. Some are on floating platforms; some are on "legs."

Fig 161–1



1. A supertanker ties up to the buoy anchored to the sea floor. The design of the buoy allows the tanker to weathervane freely as wind, waves and current change.

2. The floating hose is attached to the ship's manifold and the oil is pumped to a manifold at the base of the buoy.

3. An undersea or underground pipeline takes the oil to storage tanks either on the shore or far inland.

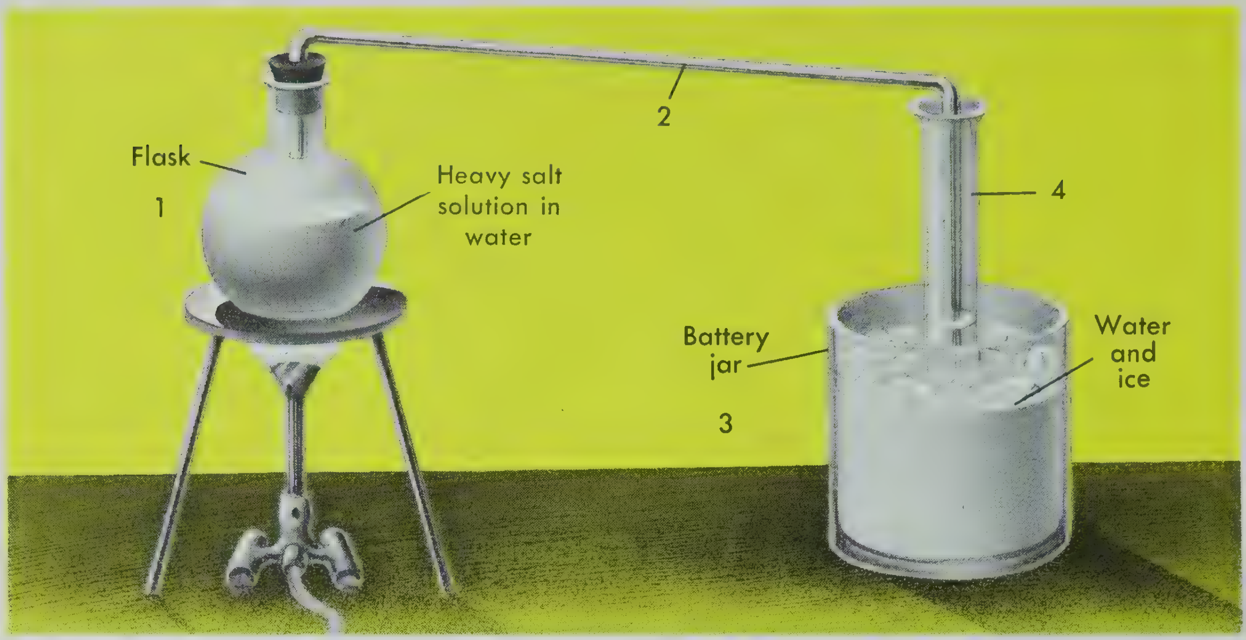


Fig. 162–1

8. FRESH WATER FROM SEAWATER?

All over the world where there is a shortage of fresh water, there are deserts. The land is arid (dry). The crops cannot grow. Farm animals cannot grow. It is a poor land where people gaze at the oceans of water around them and dream of using it. Seawater, called *brine*, cannot be used to water crops. Animals and humans cannot drink it. But if the salts could be removed, then the water could be used!

The process of removing salts from ocean water is called DESALINATION (dee-SAL-i-NAY-shun).

9. METHODS OF DESALINATION

The oldest method known is DISTILLATION (dis-til-AY-shun). Let us see how it works.

DO AND DISCOVER

Investigation 15: How can dissolved salt be removed from water?

What you do

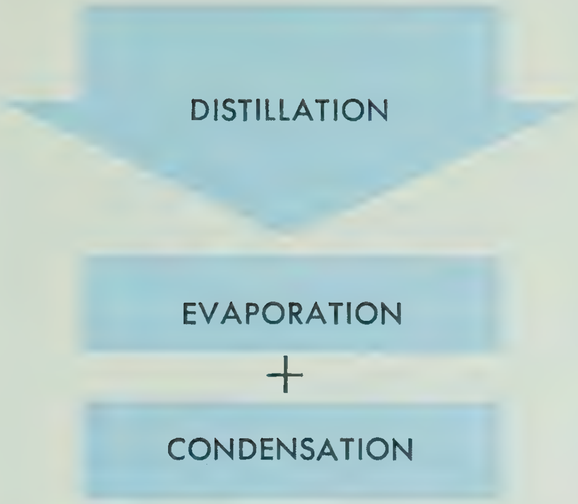
Set up the apparatus as shown in Fig. 162–1.

Heat flask 1 until all the water has boiled away. Observe the water which collects in tube 4. Allow this water to cool. Remove a drop of the water with a wood splint and touch it to the tip of your tongue.

Observations and analysis

1. What do you see on the sides of flask 1 after all the water has boiled out? Explain.
2. How does the new water taste? Explain.
3. What process is taking place in flask 1?
4. What process is taking place in tube 4?
5. Could you do this investigation without ice? Explain.

Distillation means heating the water to a boil and then *condensing* the vapor. The condensed water is pure. The



solids that remain are the salts. But heating large quantities of water is very expensive. We may find that nuclear power will be a cheaper source of heat.

A second method is freezing. As the brine freezes, the salts are squeezed out. The salts are scraped away and purer water is left. Other methods use electrical charges with special membranes for filtering solids out of seawater by pressure. The future looks very bright for having as much fresh water as we want. Perhaps, then, we shall make the deserts bloom all over the world!

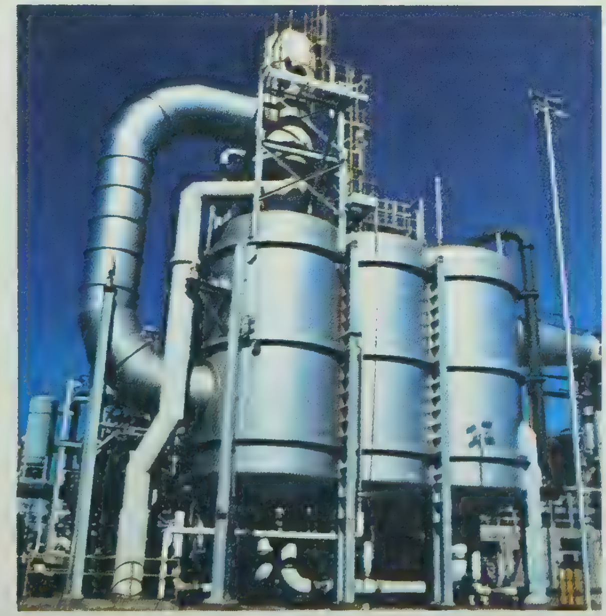


Fig. 163–1

This giant plant is desalinating seawater.

What is its source of energy?

SUMMARY OF GIFTS FROM THE SEA	
FOOD	Fish, FPC Shellfish, Whale Cod liver oil Plankton
FERTILIZERS	Dead fish Seaweed
FUELS	Petroleum oil Natural gas
CHEMICALS	Salt Bromine Iodine Magnesium
JEWELRY	Coral Gold Platinum Pearls
BUILDING PRODUCTS	Lime, Sand, Gravel
FISH PRODUCTS	Glue, Oil, Vitamins

YOU NOW KNOW

- The ocean contains valuable minerals, oil and gas.
- Desalination removes salt from ocean water to provide water for drinking and watering crops.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 22?

1. The ocean is an important source of food for people.
2. Life started in the ocean.
3. There can never be a shortage of water.
4. The ocean may provide us with minerals and other valuable items.

II. In which paragraph do you find the answer?

1. What is the chief problem of desalination?
2. What are the most important minerals coming from the sea?
3. What is chlorella?
4. How can FPC be used?

III. Knowing What and Why

1. Fish protein concentrate is made from fish by
   a. grinding and dehydration.
   b. desalination and grinding.
   c. dehydration and desalination.
   d. aquaculture.
2. Seaweed is a good source of
   a. iodine.
   b. FPC.
   c. litmus.
   d. sargassum.
3. Diatoms form food for
   a. whales and kelp.
   b. fish and kelp.
   c. fish and whales.
   d. plankton.
4. Offshore petroleum is found in
   a. the Gulf of Mexico.
   b. Hudson Bay.
   c. any ocean deep.
   d. near volcanoes.

IV. Match the words in Column B with those in Column A.

A	B
1. food chain	a. dependence
2. trilobites	b. saltwater
3. FPC	c. water plants
4. nodules	d. fish protein concentrate
5. nekton	e. swimming fish
6. brine	f. seaweed
7. aquaculture	g. chalk cliffs
8. algin	h. sea-farming
	i. manganese
	j. invertebrates

V. True or false? Explain your answer.

1. Aquaculture is not practical.
2. Raising lobsters in artificial pools does not solve the problem of a low supply of lobsters in the ocean.
3. Most fish in the ocean are useless.

VI. For the Science Reporter

1. Read about FPC. Write a report for your class.
2. Read about aquaculture in Japan. Write a report for your class.
3. Write to Office of Water Research and Technology, 18 and C Streets, N.W., Washington, D.C. 20240. Ask for free literature about nuclear plants for desalination.

23

TARGET
How can we save our oceans?

The Challenge of Ocean Pollution

Fig. 165–1
Ocean: fresh and beautiful today. What of tomorrow?

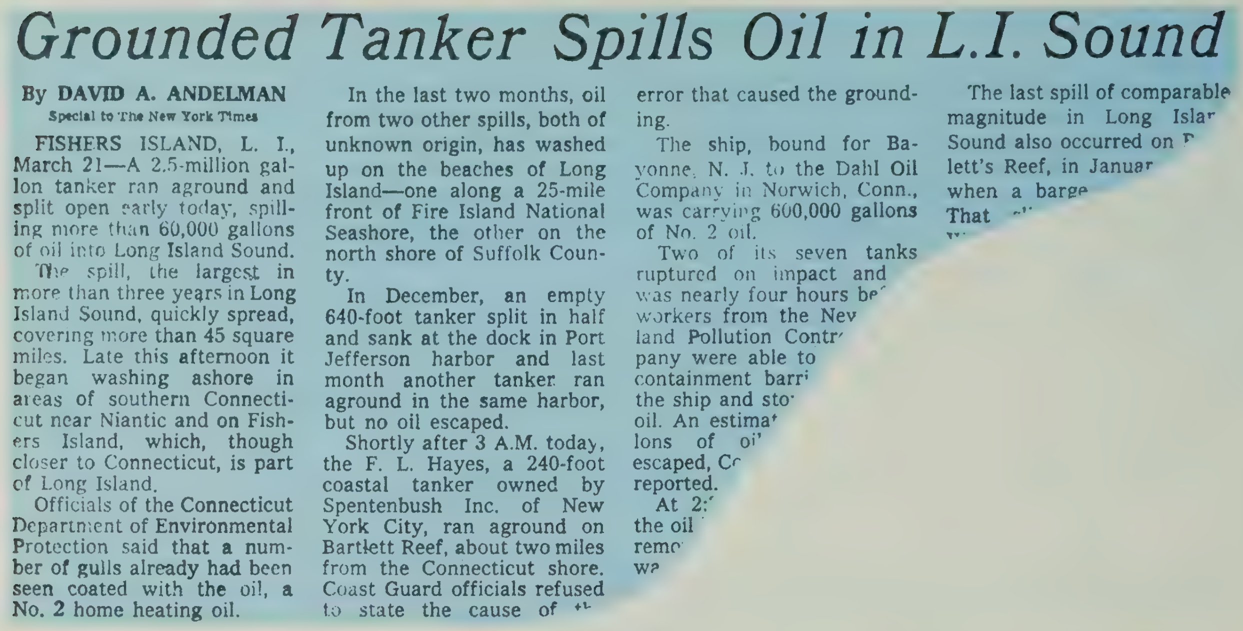
1. WHAT DO YOU MEAN, "SAVE"?

Does the Target Question mean our oceans can be *destroyed?* Well, not really. The water will be there. Will it be fresh and clear and blue and green and beautiful? Will ocean plants and ocean animals continue to grow in it? Will the ocean fish we eat poison us or kill us? What are we talking about? Of course! We are talking about pollution of the oceans.

In Chapter 10, we learned about polluted air. And now we shall see that our oceans, too, can become ugly, dirty and foul-smelling. Yes, the oceans *can* be destroyed. Yes, this is another headache in our environment.

2. HOW CAN OCEANS BECOME POLLUTED?

Air becomes polluted when we send pollutants into it. So, too, with oceans. Some of the pollutants are dumped in purposely because we have thought of the ocean as a garbage dump. Some pollutants get in by accident. Some are carried in from the air.



Grounded Tanker Spills Oil in L.I. Sound

By **DAVID A. ANDELMAN**
Special to The New York Times

FISHERS ISLAND, L. I., March 21—A 2.5-million gallon tanker ran aground and split open early today, spilling more than 60,000 gallons of oil into Long Island Sound.

The spill, the largest in more than three years in Long Island Sound, quickly spread, covering more than 45 square miles. Late this afternoon it began washing ashore in areas of southern Connecticut near Niantic and on Fishers Island, which, though closer to Connecticut, is part of Long Island.

Officials of the Connecticut Department of Environmental Protection said that a number of gulls already had been seen coated with the oil, a No. 2 home heating oil.

In the last two months, oil from two other spills, both of unknown origin, has washed up on the beaches of Long Island—one along a 25-mile front of Fire Island National Seashore, the other on the north shore of Suffolk County.

In December, an empty 640-foot tanker split in half and sank at the dock in Port Jefferson harbor and last month another tanker ran aground in the same harbor, but no oil escaped.

Shortly after 3 A.M. today, the F. L. Hayes, a 240-foot coastal tanker owned by Spentenbush Inc. of New York City, ran aground on Bartlett Reef, about two miles from the Connecticut shore. Coast Guard officials refused to state the cause of error that caused the grounding.

The ship, bound for Bayonne, N. J. to the Dahl Oil Company in Norwich, Conn., was carrying 600,000 gallons of No. 2 oil.

Two of its seven tanks ruptured on impact and
was nearly four hours be
workers from the Nev
land Pollution Contr
pany were able to
containment barri
the ship and sto
oil. An estima
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reported.

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The last spill of comparable magnitude in Long Isla
Sound also occurred on
lett's Reef, in Janua
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Fig. 166–1

A chemical test of the Pacific Ocean shows it contains ten times as much lead as it should in nature. Where did it come from? From the tailpipes of automobiles which are burning leaded gasoline. So, also, an accident in an oil tanker may foul up the ocean and our beaches.

3. TYPICAL OCEAN POLLUTANTS

The U.S. Public Health Service has listed the materials below as the most common pollutants.

4. HOW DO POLLUTANTS ENTER THE OCEANS?

Study the chart below. As you can see, some of the ways are natural; some are artificial. Do you think the natural methods can also be controlled?

*From waters of river outlets to the seas
*From fallout of particles from the air
*From rain and snow
*Brought by animals from other waters
*Brought by currents from polluted areas
*Accidental spills
*Discarded from boats

TYPICAL WATER POLLUTANTS

Pesticides: DDT, 2-4D
Oil
Radioactive materials:
  radium-226, strontium-90
Chemicals: acids, ammonia,
  arsenic chlorides, phosphates, dyes, hydrogen sulfide, lead, mercury, nitrates, tars, urea, zinc

SOLID WASTES	
paper	46%
garbage	12%
glass, etc.	10%
grass, dirt	10%
metals	8%
wood	7%
miscellaneous	7%

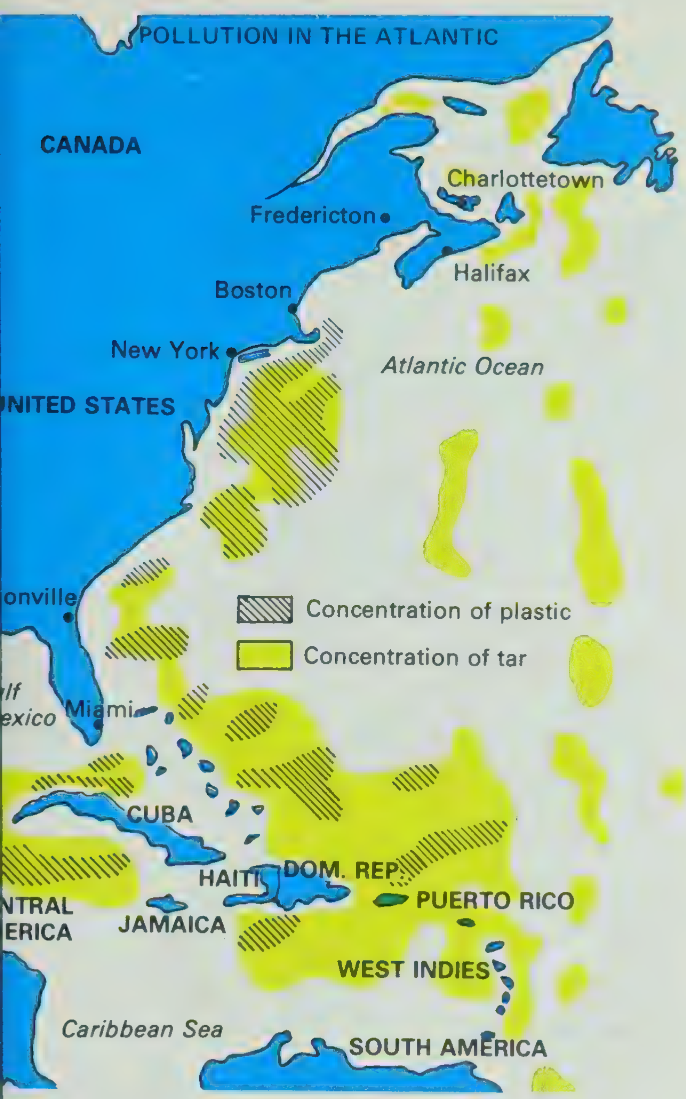

Fig. 167–1

What does this map show about the sources of ocean pollution?

5. GARBAGE—AND NO END TO IT!

Where does all the garbage go? Of course, some of it is burned. Organic garbage—food waste and toilet waste—is processed to make fertilizer. Some is sent into streams, rivers and seas. Did you know that about nine million litres of raw waste is dumped into North America's waterways every second?

Raw waste is called SEWAGE (SOO-ij). In nature, sewage is broken down by natural bacteria. Such materials are called BIODEGRADABLE (BY-oh-dee-GRAY-duh-bul) (able to be broken down by life processes).

Only organic (formerly living) materials are biodegradable. Examples are plant and vegetable scraps, meat and bone scraps. Artificial materials are not. For example the plastic spoon from your ice-cream soda is not; aluminum and iron from soda cans are not; glass is not. The nondegradable materials remain as "forever-garbage" in our waters.

YOU NOW KNOW

- Our oceans and ocean inlets are highly polluted.
- There are many kinds of pollutants.
- Pollution is caused by dumping, by industry, and by accidents.

6. WHAT'S THE DAMAGE?

"So what?" you ask. The answers have been known for a long time. But they are now becoming clearer. And the news is worse than ever.

The bad news is that pollution destroys ocean life and cuts down on our food supply. For another thing, some of the materials are brought back into our own systems to cause illness and even death. Let us examine a few of the "bad deals."

7. OIL SPILLS ARE MORE THAN A NUISANCE

The clipping on page 166 shows that the soil slick spread over 115 km^2 of water. Later it began to wash ashore on the beaches of Connecticut. How would you like to swim in these waters?

But that's not all. The clipping tells of how some of the gulls were coated with oil. As the feathers get coated, the birds cannot fly. They drown.

Oil and water do not mix. As the oil floats on the water, it cuts out light needed by green plants in food-making. The green plants die, and the food supply for fish is reduced. Also, in the food-making process, green plants make oxygen for fish. The ecology chain has been broken. Fish and other sea animals die. The human food supply has been affected.

8. TOO MUCH HEAT IN THE WATER . . .

Many electric generator plants use the water from bays and rivers to cool engines and parts. The water is usually drawn in and circulated outward. But when the water comes out, it is much, much warmer. This begins what we call THERMAL (THUR-mul) or heat pollution.

Thermal pollution causes damage to marine life. Heated water interferes with life cycles, reproduction and migration of fish and invertebrates. Warm water can kill the fish eggs and their young.

Once again, we see that pollution can interfere with natural life cycles.

Fig. 168–1

How much of this will enter our oceans? What's the damage?

9. POISONS FROM THE WATERS

Why were Alaskans warned by the Food and Drug Administration in 1970 not to eat seal livers? Why did the FDA take Vitamin D pills made from seal livers off the market?

The real problem probably began, perhaps, 1610 km away. Seals are known to migrate along the U.S. Pacific Coast. Along that coast are factories which manufacture paper from wood pulp. The waste is dumped into the ocean. The waste contains traces of mercury.

Tests on the seals' livers showed traces of the mercury. And when mercury enters the human body, it can cause brain damage. The mercury probably got into the plankton, which was eaten by fish, which were eaten by seals. The poison was moving through the "life-chain" and reached way up into Alaska!

Later, traces of mercury were also found in tuna fish and swordfish. No wonder the FDA was worried!

Fig. 169–1

A scientist performing tests on water and food can find possible causes of pollution.

10. CAN THE OCEANS BE SAVED?

Now we are back to our Target Question. We know the problem and the causes. What can we do? You are right—stop polluting. But how? And what shall we do with our wastes?

We must find new methods of waste disposal. For example, we now use RECYCLING (ree-SYK-ling) to use waste material again. Paper, glass and aluminum are recycled with great success.

We must use biodegradable materials where possible. For example, wood spoons and paper plates are biodegradable. Plastic spoons and plates are not.

We must develop detergents which do not use phosphates. Phosphates, dumped into our lakes, act as fertilizers. They may cause tremendous growth of algae and other water plants. The waters become choked with plants. The light cannot reach the plants lower down; they die and bacteria decompose them. Now there is less and less oxygen and the fish die. Today, many communities have outlawed phosphates.

Industry must find new cooling methods to avoid thermal pollution. We must control fallout of radioactive wastes from atomic energy projects. The oil industry must prevent oil spills from tankers and oil leaks from offshore drillings.

The anti-pollution fight has just begun. And, like it or not, you will be part of it.

YOU NOW KNOW

- Ocean pollution interferes with the life cycles, causing loss of food.
- Ocean pollution may cause human death.
- Ocean pollution can be controlled by education and careful industrial practices.

UNDERSTANDING WHAT YOU HAVE READ

I. What are the two main ideas in Chapter 23?

1. The oceans are polluted forever and we are in trouble.
2. The causes of ocean pollution are well understood.
3. Ocean pollution can be controlled.
4. The life cycles in oceans are really the cause of pollution.

II. What would happen in the pollution problem if:

1. all cars used only nonleaded gasoline? Explain.
2. phosphate detergents were allowed to be dumped into lakes? Explain.
3. there were no bacteria in a cesspool? Explain.

III. Knowing What and Why

1. We should not eat clams growing in polluted water because
   a. they have a terrible taste.
   b. the meat is tough.
   c. they carry phosphates.
   d. they might carry disease germs.
2. An example of a pesticide which pollutes water is
   a. DDT.
   b. mercury.
   c. Strontium-90.
   d. plastic.
3. Another title for Chapter 23 could be
   a. Water, Water Everywhere—Not A Drop To Drink!
   b. Don't Waste Water!
   c. Keep Our Ocean Clean!
   d. Industry Can Destroy Life!
4. Oil spills may
   a. cause birds to drown and fish to suffocate.
   b. cause mercury poisoning in seals.
   c. cause algae to grow rapidly.
   d. none of the above.

IV. Where do you fit in?

The following have been suggested as "citizen actions" to fight pollution. Explain how each one might be useful.

1. Use a rowboat instead of a motorboat in lake recreation.
2. Use lead-free gasoline in cars.
3. Save bottles, newspapers and food cans for collection by a recycling center.

V. Do and Discover

Place a supply of healthy aquarium plants (for example, Elodea) in a half-gallon jar, filled with water almost to the top. Gently pour a thin layer of lubricating oil on the surface of the water. Keep the jar on a window sill in bright sunlight. Observe for several days.

1. What is the object of this investigation?
2. What do you think will happen?
3. What did actually happen?
4. Can you find some way to remove the oil?

VI. For the Science Reporter.

Write to the U.S. Navy, and to the Office of Saline Water, both in Washington, D.C. Ask for information on how they treat ocean oil spills. The literature is free.

VII. Settle the Argument . . .

1. Is paper biodegradable? Explain.
2. Are rubber auto tires biodegradable? Explain.

Glossary: What Does It Mean?

ammonites	AM-ah-nites	Fossils of ancient shellfish.
aquaculture	AKWA-kul-chur	The method of growing plants and animals in ocean water.
aquanauts	AKWA-nawts	People who explore the oceans for scientific research.
Archimedes	ar-kuh-MEE-deez	Ancient Greek scientist: laws of flotation.
basalt	buh-SALT	An igneous rock of small crystals.
basin	BAY-sun	A natural depression in the earth's surface; often filled with water.
bathyscaphe	BATH-i-skayf	A powered diving sphere used for deep-sea exploration.
bathysphere	BATH-i-sfeer	A sphere which is used for deep-sea observation.
bathythermograph	BATH-i-THERMO-graf	A thermometer which is lowered into the ocean to take ocean temperatures.
benthos		Invertebrates in the ocean such as sponges and starfish.
biodegradable	BY-oh-dee-GRAY-duh-bul	Substances which can be broken down by the activities of living things; example: *decay*.
breaker		A wave as it hits the shore and breaks up into foam.
brine		Very salty water or seawater.
Carpenter, Scott		The commander of the Sealab III. Also, the only astronaut and aquanaut.
chlorella	klo-REL-uh	An experimental alga which has been used for food.

coelacanth	SEE-la-kanth	A type of fish which lived many years ago but is still found alive today in some parts of the ocean.
continental shelf		The part of the ocean floor which extends from the shore to a depth of about 180 m.
continental slope		The part of the ocean floor which extends from the continental shelf to the deep ocean.
corers	KOR-erz	Special tubes used for getting samples of sediment from the ocean bottom.
Cousteau, Captain	koos-TOE	The French commander of an underwater research vessel.
crest	KREST	The high spot on a wave.
density currents		Movements in water in which the equatorial waters move towards the poles. The cold water at the poles sinks and moves toward the equator.
deposition		The process of placing sediment in water.
desalination	dee-SAL-i-NAY-shun	The process of removing salt from seawater.
diatoms	DY-a-tomz	One-celled microscopic plants found in the ocean.
dredges	DREH-juhz	Special shovels used for getting rock samples from the ocean bottom.
echo	EK-oh	Sound waves that hit a solid object and bounce back.
echo sounding		A method of finding the ocean depth by echoes.
fathom		A distance of six feet used for measuring the depth of water.
food chain		Interdependence of plants or animals on each other. The small fish are eaten by the large fish and so on.
forams		Small animals in the sea having shells with holes.
FPC		Stands for fish protein concentrate; used as a flour.

geographer	jee-OG-ruh-fer	A scientist who studies the earth's surface and its life.
granite	GRAN-it	An igneous rock of large crystals.
Heyerdahl, Thor	Hy-ur-dahl	Norwegian scientist who studied ocean currents; captain of the Kon-Tiki.
invertebrates	in-VER-ti-brayts	Animals with no backbones.
kelp		A large brown seaweed.
line sounding		A method of finding ocean depth by using a line with knots tied in it every six feet.
mammals		Warm-blooded animals that produce milk to feed their young.
Maury, Matthew	MAW-ree	American scientist: the "Father of Oceanography."
mollusks		Invertebrates covered by a shell.
navigator	NAV-i-gay-ter	One who explores the sea.
nekton		Free-swimming animals in the sea.
nodules	NOD-youlz	Clumps of minerals found on the ocean floor.
ocean currents		The movement of the ocean's waters.
oceanography	O-shun-OG-ruh-fee	The study of the oceans; its effects, behavior, shape and content.
ooze		A deposit of mud and shells covering the ocean floor.
Piccard, Jacques	pee-KAR	The French scientist who went to the bottom of the ocean in an underwater research vessel.
plankton		Small plants and animals that float on or near the surface of oceans.
recycling	ree-SYK-ling	Remanufacture or reuse of waste materials.
ridges		A chain of mountains on the ocean floor.
ripples	RIP-ulls	Small waves caused by slow winds.
R.V.		A research vessel used to explore the oceans. It stays on the surface of the ocean.
salinity	sa-LIN-i-tee	The amount of salt in water.
Sargasso Sea		The area near the West Indies in the Atlantic Ocean which has much seaweed.

scuba	SKOO-bah	Stands for Self-Contained Underwater Breathing Apparatus.
Sealab III		A ship belonging to the U.S. Navy and used in their study of oceanography.
seaweed		A type of plankton.
sewage	SOO-ij	Raw waste.
thermal pollution	THUR-mul	Overheating of water in bays, seas and rivers by discharge of hot water from manufacturing plants.
tides		The daily rise and fall of the ocean's waters.
topography	ta-POG-ra-fee	The study of the earth's surface.
trenches		Deep places in the ocean floor.
trilobites	TRY-lo-bites	Fossils of ancient water crabs.
trough	TRAWF	The low spot of a wave.
tsunamis	tsoo-NAH-mees	Giant waves resulting from earthquakes in the ocean.
undertow		The backward pull of ocean water as it rushes from the shore under the new waves.
U.R.V.		Stands for underwater research vessel.
Verne, Jules		A science fiction writer in the 1800's.
waves		The movement of the surface water caused by friction of the wind.

Appendix

WHAT IS AN APPENDIX?

An "appendix" is something "added on." The appendix of a book is a section which has special information which can be useful.

WHAT IS MEASUREMENT?

Measurement is the act of taking measure. It is really a comparison. We compare the size, mass, or volume to a known amount. The known amount is called the *standard unit.*

In most of the world we use the *metric* (from the word, metre) system of measurement. The familiar five units of the metric system are the litre, metre, gram, second, and degrees Celsius.

FAMOUS OCEANOGRAPHIC "WORKSHOPS"

U.S. Naval Oceanographic Office	Suitland, Md.
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U.S. Coast Guard	Washington, D.C.
Smithsonian Institution	Washington, D.C.
Woods Hole Oceanographic Institution	Woods Hole, Mass.
Scripps Institution of Oceanography	La Jolla, Calif.
Texas Agricultural and Mechanical College	College Station, Texas
Oregon State University	Corvallis, Oregon
University of Rhode Island	Kingston, R.I.
University of Washington	Seattle, Washington
Johns Hopkins University	Baltimore, Md.
University of Miami	Miami, Fla.

TABLES OF MEASURE

Length

1000 mm (millimetres) = 1 m (metre)
100 cm (centimetres) = 1 m (metre)
10 dm (decimetres) = 1 m (metre)
0.001 km (kilometre) = 1 m (metre)

0.001 m (metre) = 1 mm (millimetre)
0.01 m (metre) = 1 cm (centimetre)
0.1 (metre) = 1 dm (decimetre)
1000 m (metres) = 1 km (kilometre)

Mass

1000 g (grams) = 1 kg (kilogram)
1000 kg (kilograms) = 1 t (tonne)

1 g (gram) = 0.001 kg (kilogram)
1 kg (kilogram) = 0.001 t (tonne)

Capacity

1000 mL (millilitres) = 1 L (litre)

1 mL (millilitre) = 0.001 L (litres)

Time

60 s (seconds) = 1 min (minute)
60 min (minutes) = 1 h (hour)
24 h (hours) = 1 d (day)
365 d (days) = 1 a (year)

SOME IMPORTANT TEMPERATURES

°C	
−273	Absolute zero. All motion of molecules stops.
− 79	Carbon dioxide gas becomes solid (dry ice)
− 39	Mercury freezes
0	Ice melts; water freezes
20	Average room temperature
37	Normal human body temperature
65	Pasteurization of milk (for 30 min)
100	Water boils (to steam)

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